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ADLAI E. STEVENSON, *Governor*

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SCIENTISTS—MORE OR LESS?

JAMES W. NECKERS
President, Illinois State Academy of Science

JAMES W NECKERS, *President*, 1951-1952

The year 1952 will be known as the year of the big wind. That was the prophecy of a radio wit last January first. He referred, of course, to the political campaign that is already engulfing us. Therefore, it may be appropriate to borrow the quadrenniel theme, "to view with alarm but point with pride," to consider a problem that we have as members of this Academy of Science in this year 1952.

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The members of our Junior Academy, and such as they, are the future hope of this Academy and of this country and even, possibly, of the world. They are the ones with the most apparent vigor and enthusiasm for science. They, and their leaders, are the ones who really put an enormous amount of effort into this 45th annual meeting. Right now several hundred potential scientists are raising a hubbub of scurrying effort and shrill voices in final exertions to present their year's project to the best advantage.

This year for the first time, there were seven regional Junior Academy contests, and only "First Prize" winners were eligible to come to this state meet. Long hours of effort and thought have gone into their projects, and we hope that many of them will retain their enthusiasm and thrill of attainment for years to come. This year, also for the first time, our Council has decided to reduce the time allotted to this morning session to provide in the program a definite period for the Senior Academy to see some of the results of our Junior Academy work. So I "point with pride" to one of our State Academy's greatest achievements—the promotion of a vigorous Junior Academy that has touched thousands of high school students this year. We salute them and particularly their leaders. The director of our Junior Academy, Mr. Robert Smith who worked in Herrin last year and in DeKalb now, has done a magnificent job of organization and activation. Our Council has devoted nearly one-third of its time to the problems and program of the Junior Academy, but I believe it is worth it.

But having pointed with pride, I must now "view with alarm" a seemingly anomalous condition. I refer to the decreasing number of students who are choosing science majors in college and the resulting scarcity of graduating scientists, engineers, research workers, and those entering related professional fields.

A cursory survey of the condition might lead to the conclusion that since college and university enrollments are decreasing there is a corresponding decrease in science students. But the decrease is much more than that; proportionally as well, there is a sharp decrease. If we could omit the abnormally low college enrollments during the war and the two or three years of high enrollments after the war, I believe evidence would show an alarming trend through the past fifteen years in our source of supply of science personnel.

National survey groups recently noted this problem. Industrial leaders are becoming concerned, particularly with the shortage of engineers. Several large corporations have spent thousands of dollars in advertising and in radio time to publicize this problem. Last September's *Fortune Magazine* reviewed the critical needs in this area and the same month's issue of the *Scientific American* was "solely devoted to an assessment of our human resources." Their data show that the students enrolled at present in engineering schools have so decreased in numbers that it is now predicted that in 1954 only 15,000 will be graduated, to meet an anticipated demand for 30,000. On the same

basis, present enrollments indicate 29,000 science graduates in 1954, compared to 75,000 in 1950. This is the most serious man-power shortage that America faces today. For out of the science graduates must come our future teachers and researchers who alone can produce the backlog of basic scientific knowledge upon which our future progress, and possibly even survival, will depend. The cause of these conditions, and particularly of the indicated trend, needs examination. I should like to attempt that and also indicate some remedies.

Scientists, like all other groups, are the product of heredity and environment. Since nothing can be done about the heredity contribution, environment seems to be the field to study, particularly if we consider education as a segment of environment.

Three periods in the life of the current younger generation seem worthy of examination—pre-college, college, and post-college—as contributing to the declining supply of scientists.

Free public education (not counting taxes, of course) is a laudable feature of our democracy. The percentage of our people who have completed high school is constantly increasing and the illiteracy ratio is decreasing. Compared with 25 years ago, our citizens on the average are much better educated—at least to the level where they can now understand movies, and radio and television programs. That is desirable; at least it creates a market.

But the constantly increasing population in the public schools has resulted in large classes, inadequate equipment, and not enough actual space. These conditions are coupled with an overworked teaching staff that is underpaid by any standard of qualification, compared to even semi-skilled labor.

Unfortunately, in attaining the aim of universal education, the philosophy of primary and secondary education has undergone a marked change. To achieve a higher general level of literacy, teachers often must be satisfied with a lower level of achievement. That is a serious indictment. Nevertheless, public education today is geared to the masses. The major attention is on quantity rather than quality.

A short conversation with the better teacher will soon show that this change in standards in the last quarter of a century has not been a "grass-roots" change; rather it has been imposed from above. The responsibility rests at a higher level. It comes back to the college campus to education departments, and most specifically to certain leading professional educationists. By persistent publication of their ideas and by persistent pressure on state legislatures, state departments of education, and county and city school administrators, extensive changes have been made in recent years in methods, in objectives, in curricula, and in legal requirements for our public schools. To this fraternity of educationists, change, *ipso facto*, is improvement. They feel compelled to revise their professional vocabulary every five years. An old expression is as abhorrent as milady's last year's hat. In most of these revisions they merely reverse the biblical exhortation by putting old

wine in new bottles—with a new label of course.

While these educationists have been promoting their views, college and university leaders in the old-line subject matter fields have been too engrossed in their particular areas to bother with the lower levels of education. They have neglected to insist on adequate presentation of their lines of subject matter in the lower school curricula. They assumed recognition of the need for adequate training in grammar, spelling, arithmetic, literature, and the sciences. Consequently, in the face of constant one-way pressure without counter pressures, there has been a shift in emphasis. Naturally the educationist with little training in the sciences has promoted his greatest interest. Without counterbalancing pressure, the educationist's strong points and interests will be reflected in the curricula he advises, and his weaker interests will be slighted. Thus the rise of professional Education, and the lack of interest by the supporters of the sciences and humanities, has brought about profound changes. The public school teacher has found it best to concur with the demands of the higher-ups.

Accompanying this basic change in the philosophy of public education, conditions are such that in many high schools today all students must be passed. No stigma of failure must be attached to any academic inadequacy. In many modern schools final examinations are taboo. Discipline is used only in extreme cases to protect life, if not always property. Nothing must be done to warp an adolescent personality. Students must be inspired to study, but not too much. No distasteful tasks should be assigned. Homework is frowned upon; so the student will have more time for social experiences. Students should be motivated to choose their own projects, which must be integrated into all fields of knowledge. The fact that three times as much time is necessary to accomplish some projects by this indirection must be disregarded. The primary objective is social adjustment for living in a democracy. The final product, if a student were in contact only with this system of preparation, would be a person unprepared for a practical world where one is judged by results and not effort alone, is held responsible for actions, and who would probably be fired from his first job for ignorance, indolence, and insubordination.

Dr. Fuller, who is coordinator of the Academy's Collegiate Section, has done a masterful job of pointing out the foibles and failures of the educationists in the January 1951, issue of *Scientific Monthly*.[1] If a chemical judgment could be applied to the response to this article, I should say that it produced a high heat of reaction.

At least two rebuttals of his article have been offered by educationists. One by Williams and Laurits[2] criticized his approach as unscientific. They suggested he should have used carefully collected data such as through a system of questionnaires, so beloved and revered by education leaders. Such a questionnaire, concerning the inadequacies of high

[1] Fuller, Scientific Monthly, vol. 72, pp. 32-41, 1951.
[2] Williams and Laurits, Scientific Monthly, vol. 72, pp. 282-288, 1951.

school graduates, sent to college teachers today would be about as necessary as one to support the opinion that there are fewer horse drawn vehicles now than thirty years ago. The other answer by Reeder[3] attempted to analyze the cleavage between the educationist and the academician. He stated that "the former is primarily interested in the individual, the latter in subject matter," that the liberal arts teacher does not understand the teaching-learning process leading to "the neglect on his part of any real interest in developing in his students the power to think." If Dr. Reeder implies that the product of public schools today is trained to think under the new "teaching-learning process," he has a standing invitation to disillusionment by trying to get a college freshman chemistry class to understand and use simple principles of chemistry even with "societal" applications.

Both rebuttalists dwelt extensively on the new social objectives of public school education and pleaded for the recognition of the modern system as an experiment in learning, based on research in the learning process. They may have succeeded in disparaging Dr. Fuller's appreciation of modern educational philosophy, but they failed to explain the *necessity* of the conditions he deplores. If it be granted that the old school objectives did not include enough training for citizenship and that former teaching processes were wrong, correction of those wrongs does not necessitate the abandonment of training in the fundamental tools of learning, such as a knowledge of simple mathematical processes and an ability to use the English language correctly and with some degree of efficiency. Also, many high schools in some way produce an atmosphere of mental slovenliness in which intelligence and thinking are frowned upon by the students.

One of the most serious indictments of American public education today is that, with so much attention to training for social adjustment by mass production methods, students are cut to the same pattern and level. Secondary education now tends to produce followers, not leaders. But democracy must also have leaders. It must encourage individuals with originality, independence and even eccentricities. Elementary and secondary schools are urged to use all kinds of tests and techniques to help the backward child, which is as it should be; but a corresponding program for the development of the brilliant student is usually lacking.

It seems reasonable that as much special attention should be given to those in the upper quartile as to the lowest 25 per cent in intelligence. In the larger schools at least, the better students could be recognized early in high school and given special courses in addition to the regular work, or as a substitute for some of the less challenging courses or activities. Such work in the basic academic fields would help future leaders to get much more out of college. Our school administrators recognize different levels of ability in physical activities and have special programs to develop the best for winning athletic teams. It is certainly just as important to recognize and give special

[3] Reeder, Am. Assoc. Univ. Prof. Bull. 37, pp. 506-521.

attention to those with mental superiority. At least they should occasionally be challenged to the limit of their mentality, rather than confined to activities that produce mental laziness.

Last year a bulletin was produced in this state by the Illinois Secondary School Curriculum Program entitled "The Schools and National Security" and labeled further "Recommendations for Elementary and Secondary Schools." In many respects it is a very complete manual for the schools. But although its 296 pages contain numerous references to training for "followership," there are only two references to leadership, one a fleeting mention in the introduction and the other in the section on Science Education. All the current brand of "pedaguese" is there, such as "undergirding," "psychological climate," "societal strength," and "group interaction," but the superior student is ignored.

The point is this—science subjects are the most difficult in the curriculum; they attract the superior students. But if superiority is neglected and mediocrity is encouraged, from whence will come our future scientists? "If the salt have lost its savour, wherewith shall it be salted?" Science subjects in many high schools are going by default. One high school in southern Illinois had five sections of high school chemistry twelve years ago, last year it had one. The reason or excuse: chemistry is too hard, the students won't take it. In this era of encouraging students to make their own choice, even through the omniscient ages of six to sixteen, the easy road is chosen, the challenging and difficult one is by-passed.

One more observation—one of the latest developments in education (I hope it is not another fad) is *guidance*, and through it, the future of science might be saved. However, the guidance program in too many schools is in the hands of those who have little understanding of the methods, the demands, and even the contributions of science. Our schools need guidance personnel with an interest in science and its future—persons who will early find young students with the proper qualifications and will urge them to prepare for that field. As it now is, in most cases, the over-all approach and interpretation is social. The result is that potential scientists may be guided away from a field for which the guider has little sympathy. It is possible that some of these so-called guidance experts, along with social-minded directors, are accomplishing an objective that is held by some—that the progress of science should be stopped for a while to give the social forces a chance to catch up. If this be true, the future security of our country is at stake and guidance to the guidance program is indicated.

So again I point with pride to this year's program of the Junior Academy. It is active in spite of competing forces and its leaders should be commended. The young participants may be the valiant vestige of a vanishing race.

Let us now follow the progress of a young, potential scientist on a college or university campus. The average entering freshman, particularly in state-supported schools, has but little facility with simple mathe-

matical tools and a restricted comprehension of the uses for rhetoric and a vocabulary. His scholastic record has been compiled through memory and mimicry, rather than ability to think. Awaiting him in most undergraduate circles is an atmosphere of mental indolence where the primary goal is only the accumulation of the required credits for graduation with the minimum of mental exertion. How else can one explain the emphasis on choosing easy courses with the easiest instructors and an abstinence from activities that are not entertaining.

Part of this atmosphere is created by the student body. Many of the collegiate populace, as elsewhere, have succumbed to the easy way of the dole, of grabbing much but giving little, of following rather than leading. More and more often students are encountered, when a class subject involves new ventures of complex thought, who blithely tune out their mental receiving set and sit out the period in a blissful vacuum. This mental lethargy has always been the bane of teachers, but seldom has it been as broad and deep as it is today.

But not all of this pervading atmosphere is of student origin; college administrative practices also contribute to it. Qualitative standards of admission beyond possession of a high school diploma are constantly being attacked and often relaxed. In the competition for larger student bodies, quality is sacrificed for quantity. Standards of retention and readmission are lowered. Popularity contests by departments and teachers are condoned. Courses involving only craftsmanship or memory supplant those that require thought and reasoning. Curricula that produce trained technicians rather than educated individuals are accepted. And finally, many professional student counsellors encourage procedures in which failures are rationalized and plain evidence of sheer laziness and mental incapacity is disregarded.

It is related that shortly after Thoreau was graduated from Harvard in 1837 he spent an evening with Emerson discussing, among other things, higher education. Emerson congratulated Thoreau on his attaining the baccalaureate from such a great university and said, "You should be proud to be an alumnus of Harvard. Just think, it teaches every branch of knowledge." Thoreau's reply was: "Yes, every branch of knowledge and none of its roots."

Possibly it was ever thus, but certainly now even more. In such an academic atmosphere as we now too often have, it is remarkable that as many students as do, choose to be science majors. With subject matter that requires thought and understanding, intensive study and long laboratory hours, it is surprising that many more do not take the easier road to academic degrees. It is encouraging to examine scholastic honor rolls and find them dominated by science majors in the more difficult curricula. So our more rigorous demands attract the more virile students; for that we can be thankful. We do get the cream of the crop, but there is danger that the cream will not continue in supply with the trend toward homogenization in secondary education. And

the constant efforts to dilute that cream in higher educational environments make it increasingly difficult to whip it into its necessary useful form.

But students themselves and college administrators do not create all the obstacles to the production of scientists. The college teacher is also a party to discouragement. Frankly, some are just not good teachers. Some are lazy. Others seemingly exhaust themselves getting higher degrees and coast forever after. Some look upon teaching chiefly as a means of livelihood and it becomes that only. Others become bored with the fundamental, elementary subject matter that must be presented over and over. They forget that, although it is old stuff to them, it may be new and challenging to an ever-recurring audience that is hearing it for the first time. To them also, laboratory experiments become only necessary routine, rather than a means for illustrating interesting phenomena and for developing powers of observation, reasoning, deduction and scientific conclusions. All too often experience in teaching becomes synonymous with impatience with student difficulties, intolerance of new ideas and methods, uninspiring presentation of subject matter, and deadening, turn-the-crank automatism.

To some, teaching is frankly secondary, following other personal and professional interests. It becomes an unimportant but necessary obligation. This attitude is often aided and abetted by higher officials, particularly in universities where advancement is based primarily on research and administrative duties.

All of these attitudes of students, administrators and teachers are basic contributors to the easier way. A continuing flow of scientists and leaders can not arise from such an atmosphere of *laissez faire* and languid methods. It is up to science teachers in particular to promote attitudes and actualities of high scholarship, research, and thought, so that our colleges may continue to promote learning and education rather than becoming institutes of mere training and propaganda. Such a program should yield educated leaders, not just trained robots.

One other point. Although science is completely impersonal, it is subject to applications thought up by human minds. Thus many people consider science more a menace than a support, due to applications supplied by evil or desperate minds. This presents another challenge—to transmit to the nonscience student an appreciation, and if possible an understanding of the methods, the objectives, and the contributions of science in this modern age. One cannot afford to disregard a group that in later years may sit in judgment. That also necessitates a coordinate obligation—that science students must understand better and be able to assume their responsibility to society. As the recent Harvard Report states, they should acquire abilities "to think effectively, to communicate thought, to make relevant judgments, to discriminate among values." Particularly since the last war have those objectives become significant and curricular changes to meet them have followed in the field of general education. As one observer said, "M. I. T. is humanizing

the sciences and Harvard is simonizing the humanities." Incidentally, as you might suspect, that remark came from a Princeton man.

Toynbee, the English historian, propounds that the Christian Church was the bridge between the Hellenic civilization and our modern Western civilization. So too the colleges, and particularly the college science teachers, are the major link between the raw material of the younger generation and the future advance of science. That is a profound obligation.

And finally, the circumstances that await a bachelor scientist also need some examination. Conditions in our present economic and political muddle contribute little to the attractiveness of a scientific career. The freshman who now chooses science does so in the certainty that at the end of four years of special training he will have two immediate prospects—at least two years of military service, or employment at a salary less than that of a skilled workman. Neither prospect lends much inducement to embarking on a course of study that requires brainpower, perseverence, and long hours in study of difficult subject matter when much easier ways are open. Until such conditions are changed, there will be little change in the downward trend of supply.

The law of supply and demand eventually should remove the economic difficulty, even without benefit of union organization and tactics. But our economy and industry can not wait for that. A campaign of action and recruitment down to the lowest levels of training is needed to reverse present trends.

The other condition is in the hands of the military and political leaders. They have been told, and they themselves say, that modern warfare, and therefore probable survival, depends upon superiority in technology and scientific developments. Nevertheless, their concept of available manpower seems to be concerned only with supplying operators of massive quantities of guns, planes, tanks, supply trucks and ships. Admiral Moreell said last September that "if we are to have this power, we must have available the scientists and engineers who can devise, design and build the instruments of modern war."

Young men need encouragement to complete their scientific training. Many of them with true patriotic feeling do not seek the possible onus of deferment. But if scientists are even more necessary than soldiers and sailors, then students in scientific courses should be as honored, and deferred, as are students at West Point and Annapolis. Further, to prevent diversion of available graduating scientists to the armed forces, provision should be made for immediate use of their scientific training upon graduation. It would not seem unreasonable to organize a Science Corps, with a distinctive uniform, that would be just as honored in national service as one of the military units. A two-year period of enlistment could be required. The personnel of such a Science Corps could be assembled in the summer following graduation and given a three-months basic training course, if the military mind must be satisfied. In the fall, on the basis of predetermined qualifications, the members

of this Science Corps could be dispersed to graduate schools, atomic energy projects, proving grounds, or vital industries, as the need demands. At the end of their enlistment period, the individuals would revert to citizen or reserve status or could continue in the Corps, as do the military school or ROTC enlistees.

Perhaps the deferrment of successful college students and the appointment of the Scientific Manpower Advisory Commission indicate a realization of the errors made in the last war. If so, it is a step in the right direction. But until a definite policy is implemented that will permit science students to complete their college training and that will make specific use of that training after graduation, curricula in science will not be on the preferred basis that they deserve for the future survival of democracy.

In conclusion, a critical analysis such as this should include suggestions for remedy. If all the persons involved in the available supply of scientists can agree that more scientists are needed to promote better living and to protect our way of life, then a program should be produced that will work to those ends.

Robert Millikan[4] in his *Autobiography* places a challenging responsibility on our high schools when he says: "The key to the future of America clearly lies in the secondary school because it is the only American institution that now reaches practically the whole oncoming generation." With that responsibility in mind, here are some suggestions to the teachers and leaders in secondary education.

1. Continue emphasis of training students for responsible citizenship; it is a necessary program.
2. Continue to adapt courses to students through experimentation, but use a more scientific approach in judging the new and the old.
3. Give better training in the fundamentals of rhetoric and arithmetic for better understanding and progress in a technological age, and for future learning.
4. Promote a program to recognize, train, and reward the better minds and personalities for potential leadership, as in athletics. Don't level the mountains to fill the valleys.
5. Because of the critical importance of science in this day, use the guidance program to swell the ranks in that field with students having the proper aptitudes and intelligence.

Next, to the college and university group, on whom rests the actual production of professional personnel, and with obligations to promulgate and to promote science, these recommendations:

1. Recognize that research in educational methods does produce better insight into the teaching-learning process, and adapt college methods to produce better results.
2. Never forget that college classes are made up of individuals with different needs and aims, and are not amenable to "turn the crank" procedures.

[4] Millikan, The Autobiography of Robert A. Millikan: New York, Prentice-Hall, p. 43, 1950.

Be open-minded and fair, tolerant and considerate.

3. Abhor slothfulness in teaching; permit no other activities and interests to assume primary attention. Give the best efforts and expect them in return. There is no substitute for competence and sincerity in college teaching.
4. Sell science and recruit the best prospects.
5. Hold to high standards, even in a declining environment. Require results and understanding, not merely efforts.
6. Inspire a respect for truth, ethics, accuracy, exactness, and clarity. Emphasize principles over facts and reasoning over memory. Above all, try to make students think.

Finally, those who control the destiny and ultimate use of scientific manpower can easily nullify the best efforts to recruit for, and enhance the quality of, those ranks. They must recognize that recruitment to a course of difficult subject matter, demanding intensive effort, is of little avail unless the student can be assured that his talents will be used in a professional manner that will yield personal pride, dignity, and security.

To that end, industrial, military, and political leaders should:

1. Define a program for the future that can be relied upon rather than one that is full of uncertainties for the college science student.
2. If science is one of the backlogs of national security, and if a period of national service is to be required of all young men, set up a program of science service that would parallel military service with equal prestige and relief of obligation.
3. Encourage young people to choose science by making conditions of employment attractive, professional, and dignified. Raise the ethical standards of business so that employment will engender a feeling of pride and even of service.
4. Recognize the importance of public opinion and promote a program that will substitute knowledge and understanding for superstition and fear.

Henry D. Smyth, of the Atomic Energy Commission and previously of Manhattan Project fame says: "Basic scientific research is the foundation of modern technology. A vigorous technology is essential for economic welfare in the world of today. It is necessary for the defense of a free society. It has become the very sword and buckler of freedom."[5] If that be true, all of us in the production line of future scientists should make every effort to expand and improve our work, so that we need not "view with alarm" but rather can continue to "point with pride" to our national preeminence in scientific achievement, and to the products of our schools, the young men and women who can make that possible.

[5] Smyth, Am. Sci., vol. 38, p. 436, 1950.

PROGRAM FOR THE 45th ANNUAL MEETING
PAPERS PRESENTED

ARCHAEOLOGY AND ANTHROPOLOGY

DR. DAN MORSE, *Chairman*
Peoria

*Studies of Shapes and Patterns of Flint Artifacts Found Along the Mackinaw River: C. W. Hudelson, Illinois State Normal University, Normal.

The Part of the Amateur in Archaeology: Claude U. Stone, President, Illinois State Archaeological Society.

The Section of Anthropology, Illinois Academy of Science, A Review of Its Past Activities: C. C. Burford, Urbana.

An Archaeological Survey of the Crab Orchard Lake Area in Williamson and Jackson Counties, Illinois: Irvin Peithman, Southern Illinois University, Carbondale.

The Kingston Lake Site, Peoria County: E. C. Bessler, Peoria.

Some Archaeology of the Charleston Area: William Beeson, University of Illinois, Urbana.

BOTANY

Section A

WILSON N. STEWART, *Chairman*
University of Illinois, Urbana

Colchicine and the Concept of C-Mitosis: O. J. Eigsti, Funk Brothers Seed Company, Bloomington.

An Analysis of the Microstructure of the Wood of the Three Species of Taxodium: Margaret Kaeiser, Southern Illinois University, Carbondale.

The Anatomy of the Xylem and the Phylogeny of the Julianiaceae: William L. Stern, University of Illinois, Urbana.

Psaronii distichi, Fossil Ferns of the Paleozoic: Jeanne Morgan, University of Illinois, Urbana.

Additional Notes on the Anatomy of Heterangium: Theodore Delevoryas, University of Illinois, Urbana.

Additional Observations on Rotodontiospernum illinoiense: Wilson N. Stewart, University of Illinois, Urbana.

Section B

KENNETH E. DAMANN, *Chairman*
Eastern Illinois State College, Charleston

Color Forms of Plants in Illinois: Harry E. Ahles and Franklin C. Lane, University of Illinois, Urbana.

*Check List of Fleshy Fungi Collected in West-Central Illinois: Minnie May Johnson, Stephens College, Columbia, Missouri.

*Initial Report on the Mosses of McDonough County, Illinois; Jean S. Morrow, Western Illinois State College, Macomb.

A Phytosociological Study of an Oak-Hickory Woods in West-Central Illinois: Paul C. Murphy and R. Maurice Myers, Western Illinois State College, Macomb.

A Study of Microclimates in an Oak-Hickory Woods and an Adjoining Prairie Area in West-Central Illinois: William E. McCormick and R. Maurice Myers, Western Illinois State College, Macomb.

*Growth of a Managed Eastern White Pine Plantation in Northern Illinois: Ralph W. Lorenz, University of Illinois, Urbana.

Demonstration of Hybridization in Marsilea: H. F. Thut, Eastern Illinois State College, Charleston.

* Published in this volume.

Section C

KENNETH E. DAMANN, *Chairman*

The Development and Structure of the Maize Chloroplast as Interpreted with the Electron Microscope: Albert E. Vatter, Jr., University of Illinois, Urbana.
Virus-Like Particles from Elm Phloem Necrosis: H. H. Thornberry, University of Illinois, Urbana.
*The Behavior of Oak Wilt (Chalara quericina, Henry): J. Nelson Spaeth, University of Illinois, Urbana.
A Pilgrimage to the Land of Linnaeus; Evelyn I. Fernald, Rockford College, Rockford.
*The Ralph Emerson Preserve, Rockford, Illinois—An Outdoor Botanical Laboratory for Rockford College: Evelyn I. Fernald, Rockford College, Rockford. Read by title.
The Lorado Taft Field Campus of Northern Illinois State College at Oregon, Illinois: Robert A. Bullington, Northern Illinois State Teachers College, DeKalb.
*A Mesophytic Forest on the Upland Prairie in East-Central Illinois: Richard Hudnut, Eastern Illinois State College, Charleston.
A Relict Plant Community in East-Central Illinois: Ernest L. Stover, Eastern Illinois State College, Charleston.

CHEMISTRY

Section A

G. W. THIESSEN, *Chairman*
Monmouth College, Monmouth

*Relative Abundance of the Elements: Carl R. Meloy, University of Illinois, Navy Pier, Chicago.
Adsorption Phenomena: Bhagat Singh, Bradley University, Peoria.
*Zinc Oxide for the Removal of Phosphates: W. F. Bailey, MacMurray College, Jacksonville.
Air Constant Temperature Bath: K. Van Lente and Elbert H. Hadley, Southern Illinois University, Carbondale.
Research and Development in Ceramic Engineering: A. I. Andrews, University of Illinois, Urbana.

Section B

*Some New Duclaux Constants: G. R. Yohe and Myra W. Lansford: State Geological Survey, Urbana.
Re-Use of Organic Preparations: C. W. Bennett, Western Illinois State College, Macomb.
Polymerization of Itaconic Anhydride: Mark C. Paulson, Bradley University, Peoria.
Direct-Reading Conductivity Bridge: G. Thiessen and J. Wertz, Monmouth College, Monmouth.
Application of the Leuckart Reaction to Thiophene Chemistry: D. R. Smith, James Millikin University, Decatur.

GEOGRAPHY

DALIAS A. PRICE, *Chairman*
Southern Illinois University, Carbondale

*Theory of Industrial Expansion: Charles C. Colby, Southern Illinois University, Carbondale; Professor Emeritus, University of Chicago, Chicago.

* Published in this volume.

Educational Travel in a Teacher-Training Program: Reece A. Jones, Western Illinois State College, Macomb.

*One Square Mile of Ice—An Experiment in Geographical Analysis: H. R. Thompson, University of Illinois, Urbana.

*A Map of the Relative Relief of Illinois: Wesley Calef, University of Chicago, Chicago.

*A Survey of Illinois Water Sources Distribution and Present Supply Problems, as Exemplified at Joliet and Charleston: Stanley A. Changnon, Jr., University of Illinois, Urbana.

*A Method of Constructing Average Slope Maps with Northwestern Illinois as an Example: Richard S. Thoman, University of Chicago, Chicago.

GEOLOGY

HEINZ A. LOWENSTAM, *Chairman*
University of Chicago, Chicago

*Oneota Formation, Stoddard Quadrangle, Wisconsin: Gilbert O. Raasch, State Geological Survey, Urbana.

Heavy Minerals of the Peorian Loess in the Peoria Area: Dorothy J. Gore, State Geological Survey, Urbana.

Experimental Studies of Lead Sulfide Solubility and Its Relation to Ore Deposition: J. J. Hemley, Northwestern University, Evanston.

*Environmental Control of Iron Mineral Deposition: N. King Huber, Northwestern University, Evanston.

Ceramic Materials from Magnesium-Treated Clays: William D. Johns, University of Illinois, Urbana.

*Some New Observations on Niagaran Reefs in Illinois: Heinz A. Lowenstam, University of Chicago, Chicago.

*The Chouteau Formation of Illinois: T. C. Buschbach, State Geological Survey, Urbana.

A Hamilton County Core and Its Bearing on Ste. Genevieve-Aux Vases Relations in Illinois: Elwood Atherton, State Geological Survey, Urbana.

*The Earliest Publication on American Geology—Thomas Hariot, 1588: George W. White, University of Illinois, Urbana.

PHYSICS

GLENN Q. LEFLER, *Chairman*
Eastern Illinois State College, Charleston

Color Photography and Science Projects: H. L. Rider, Maine Township High School, Des Plaines.

Examining Students in Elementary Physics: R. F. Paton, University of Illinois, Urbana.

A Laboratory Time-Saver for Use in Introductory Electronics: R. C. Waddell, Eastern Illinois State College, Charleston.

*Circuits for Photometry: G. R. Peirce, University of Illinois, Urbana.

*Two Simple Photometric Techniques: Howard C. Roberts, University of Illinois, Urbana.

*Reversal of Direction of Arc Movement in a Magnetic Field: Arthur L. Riche, Vice-President, Micro Switch, Freeport.

Imperfections in Crystals: Robert Maurer, University of Illinois, Urbana.

Beta-Ray Spectrometers: Max C. Bolen, Millikin University, Decatur.

Nuclear Physics for Civil Defense Nurses: William Azbell, Bradley University, Peoria.

*Variation of the Dielectric Constant of Dimethyl Silicone with Temperature: O. B. Young and C. E. Dickerman, Southern Illinois University.

*Published in this volume.

PSYCHOLOGY AND EDUCATION

H. W. CRALL, *Chairman*
Western Illinois State College, Macomb

The Improvement of the Workbook in Secondary School Biology: Gordon E. Peterson, Greenville High School, Greenville.
How to Keep Biology Alive: Dorothy Butts, East High School, Rockford.
The Educational Uses of the Lorado Taft Field Campus at Oregon, Illinois: Robert A. Bullington, Northern Illinois State Teachers College, DeKalb.
Certain Factors Related to Student Teaching in the Laboratory School of the University of Missouri: Eugene B. Grant, Northern Illinois State Teachers College, DeKalb.
*A Study of the Physical Growth of 4-H Club Boys and Girls in Illinois: D. M. Hall, University of Illinois, Urbana.
The Implications of Physical Deviations and of Physical Abnormalities in Children of the Elementary School: Margaret M. Schannenk, Western Illinois State College, Macomb.
A Study of the Relationships of High School Training to Out-of-School Status and Occupations of Youth of Lee County, Iowa: Warren O. Covert, Western Illinois State College, Macomb.
A Report on the Nebraska Program of Educational Enrichment Through the Use of Motion Pictures: Jack A. Peterson, Western Illinois State College, Macomb.
The 2 x 2 Slide as an Aid in the Problem-Solving Type of Teaching: John H. Woodburn, Illinois State Normal University, Normal.
Advanced Biology for the College Preparatory Student: Robert Kemman, Arlington Heights Township High School, Arlington Heights.
Photomicrographs as a Laboratory Teaching Aid: Norman O. Levardsen and Norman L. Biggs, Northern Illinois State Teachers College, DeKalb.

SOCIAL SCIENCE

DONALD E. WRAY, *Chairman*
University of Illinois, Urbana

Philippine Prospect: Aiden Cutshall, University of Illinois, Navy Pier, Chicago.
Swedish Social Policies: David E. Lindstrom, University of Illinois, Urbana.
Real-Estate Activity in Southern Illinois: Lewis A. Maverick, Southern Illinois University, Carbondale.
*Folkways and Mores in a Greek-American Community: Grace M. Jaffe, Barat College, Lake Forest, Illinois.

ZOOLOGY

THEODORE N. TAHMISIAN, *Chairman*
Argonne National Laboratory, Chicago

Cellular Effects of Radiations: Dr. E. L. Powers, Argonne National Laboratory, Chicago. Guest speaker.
*Physiologically Paired Factors and Master Factors of the Animal Environment: V. E. Shelford, University of Illinois, Urbana.
Chemical Mutagenesis in Drosophila: J. A. DiPaola, Loyola University, Chicago.
*Inheritance of and Frequency of Y Gene in the Tussock Moth, Hemerocompa leucostigma: S. Mittler, Illinois Institute of Technology, Chicago.
*Response of Gonads of Frog Larvae to Chorionic Gonadotropins: C. L. Foote, Southern Illinois University, Carbondale.
*Variations in the White Blood Cells of Normal and Red Leg Frogs: H. M. Kaplan, Southern Illinois University, Carbondale.

* Published in this volume.

Seasonal Changes in the Energy Balance of the English Sparrow: E. A. Davis, Jr., University of Illinois, Urbana.

Mechanics of Filter Feeding of Mosquito Larva: W. R. Horsfall, University of Illinois, Urbana.

The Macro-Araneae (Large Spiders) of Illinois: A. G. Wright, Illinois State Museum, Springfield.

*Neotropical Exodont Braconidea: G. T. Riegel, Eastern Illinois State College, Charleston.

The Use of Pentothal Sodium in Preparation of Preserved Specimens: A. G. Smith, Loyola University, Chicago.

Additional Records of Amphibians and Reptiles of Southern Illinois: H. A. Stein, Southern Illinois University, Carbondale.

Dissemination of the Four-O'Clock Bug Catorhintha Mendica Stal and Its Host Plant, Mirabilis nyctaginea (Mich.): W. V. Balduf, University of Illinois, Urbana.

Cercarial Origin in Ripidocotyle septpapillata, Krull 1934 (Trematoda, Bucephalidae): V. B. Kniskern, Eastern Illinois State College, Charleston.

*The Effects of Some Detergents on the Developmental Stages of Horse Strongyles: N. D. Levine and Virginia Ivens, University of Illinois, Urbana.

Behavior as Determining Environment: C. E. Abbott, Agersborg Biological Laboratory, Centralia.

The Importance of Comparative Histology in Liberal Arts and Medical Education: H. P. K. Agersborg, Agersborg Biological Laboratory, Centralia.

Preliminary Report on the Study of Ecology of a Clear-Water Stream in Southern Illinois: W. M. Gersbacher, Southern Illinois University, Carbondale. Read by title.

*Additional Pseudoscorpions from Illinois: C. C. Hoff, University of New Mexico, Albuquerque, New Mexico. Read by title.

COLLEGIATE SECTION

HARRY J. FULLER, *Coordinator*
University of Illinois, Urbana

JACQUELINE RUDA, *Chairman*
Illinois Wesleyan University, Bloomington

*Caves of the Kinkaid Limestone Near Cobden, Illinois: Stanley E. Harris, Jr., and Bill Dean Allen, Southern Illinois University, Carbondale.

Preliminary Report on the Pleistocene History of the Big Muddy Basin in Southern Illinois: Stanley C. Harris, Southern Illinois University, Carbondale.

Elementary Weather Station: G. P. Stevens and G. R. Bell, Northern Illinois State Teachers College, DeKalb.

*The Ericaceae of Illinois: Martha Bell, University of Illinois, Urbana.

Undergraduate Experiments in Radioactivity: John W. Spokas, St. Procopius College, Lisle.

Studies with an Electron Microscope: Vivian Krespin, Rockford College, Rockford.

A Report on the Bryophyta of Stone County, Arkansas: Raymond C. Hatcher, Southern Illinois University, Carbondale.

Seasonal Fluctuation of Hemoglobin in College Men and Women: Helen Ralston and Marianne Whowell, Monmouth College, Monmouth.

A Study of Silica Precipitated from Saline Solution: Robert T. Smith, The Principia, Elsah.

The Study of Phases of the Distribution of Colloidal Silicia in Nature: David A. Fanta, The Principia, Elsah.

* Published in this volume.

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ARCHAEOLOGY AND ANTHROPOLOGY

STUDIES OF SHAPES AND PATTERNS OF FLINT ARTIFACTS FOUND ALONG THE MACKINAW RIVER

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One of the most valuable and fascinating discoveries made by early man was the knowledge that flint could be made into very useful cutting tools. It was discovered that this kind of quartz could be chipped in any direction, and that straight, long, even pieces could be struck off from large cores. Because flint is very hard, the edges of cutting tools such as knives, celts, spearheads, arrowheads, would remain sharp even with very rough usage.

It is difficult to set up cleancut dividing lines between the various types of flint artifacts which were made by the Indians. Whether a flint artifact is a spearhead or an arrow point, a scraper or a perforator, is often difficult to determine. A medium-sized flint artifact might have been put to any one of several uses, depending upon the length or shape of the handle set onto the tool.

It must not be assumed that size is an important factor in deciding the use made of flint tools. The same shapes were produced in many sizes. The variation of size may change the character, use, and name of the artifact; it may, according to size, become an implement used for cultivating the soil, a spear, dagger, fish knife, or an arrow point.

Also, the relative thinness of specimens must be borne in mind in classifying these objects: If thick, heavy, and large, they might require more force to puncture the body of an animal than an Indian could command.

Flint artifacts have been classified by many experts, but most classifications fail to satisfy anyone except the originator of the scheme.

Some tribes of Indians have made characteristically shaped arrow points. The Iroquois arrow points were almost always thin and triangular. Triangular points were used regularly by the Cherokees and occasionally by the Algonquians, but they were much thicker and heavier than the Iroquois points It is recorded that the Fort Ancient people used a serrated triangular point. It is believed that practically every tribe of Indians in Kentucky had one or two, but not more than a few, types which were regular for definite purposes.

It is thought that the spear belongs to an earlier era in man's civilization than does the arrow. The spears are not common as tools.

A number of flint blades, both large and small, are found with beveled cutting edges. These beveled-edge points cause the flying arrow to rotate. However, the so-called beveled arrows are apparently too thick to penetrate, especially while whirling, and are probably resharp-

ened knives. The most practical theory now is that beveled flints were used in skinning animals. The bevel is usually such as would be necessary if the blade were held in the right hand and pulled toward the user.

Millions of arrowheads have been found in the United States on ancient camp sites, near fishing streams, and along rivers. It is reasonable to believe that the Indians needed many more arrow points than knives or spearheads. The great numbers of flint points found is an indication of the antiquity of man in North and South America.

The variety of arrows was determined by the climate of the particular district involved, the materials available, the topography of the land, the occurrence of water, and the kind and distribution of game animals. The larger and more delicate flint blades were probably used as ceremonial pieces, for they were too brittle to stand rough usage. They often exhibited extra-fine quality of workmanship and design. Certain flint chippers apparently took artistic pride in making unusual and unique shapes, hook-like artifacts, charms of various sorts, and fetishes to suit their own whims as well as the whims of those whom they served. A number of these designs show unusual symmetry, pattern, and beauty.

I have placed these artifacts into several groups based largely on the shape, pattern, and quality of workmanship. In a few cases I have pointed out what I think demonstrates a special interest and taste in the colors of the flints.

Group I (fig. 1).—Arrowheads with straight base, horizontal notches, and thin bodies. Most of the specimens are 1⅛″ to 1⅝″ in length; one is 3¼″ long. Most of these pieces have convex edges. The workmanship is fine.

Group II (fig. 2).—These arrowheads are of Hopewelleian type with owl-like bases. The base is extremely concave, forming points at outside corners. The edges are straight with a broad center axis. Most of the pieces are about 2⅛″ to 3½″ in length. Workmanship is good to fine.

Group III (fig. 3).—Arrowheads with a deeply concave base. Long points are formed at outside corners of the base. The edges are straight. The workmanship is fair to good. The pieces average from 1⅛″ to 1⅝″ in length.

Group IV (fig. 4).—Long slender celts are projectile-like pieces with straight bases. The edges are convex. These celts are thick in the middle and taper to each end. Pieces average 2¼″ to 3½″ in length. These celts have been found in considerable numbers in fields on both sides of Wyatt Ford. Very few are found at any other sites.

Group V (fig. 5).—Hammer stones—round-like or roughly spherical—are rather brittle when made from quartz, chert, and flint. Hence, medium to large sections have broken off many of these. Most hammerstones fit well into the palm of the hand. These pieces are 1¾″ to 2⅞″ in length.

Group VI (fig. 6).—The flint scrapers have one edge that is sharply worked for scraping bones or wood. Scrapers are sometimes made from broken arrows or celts. The

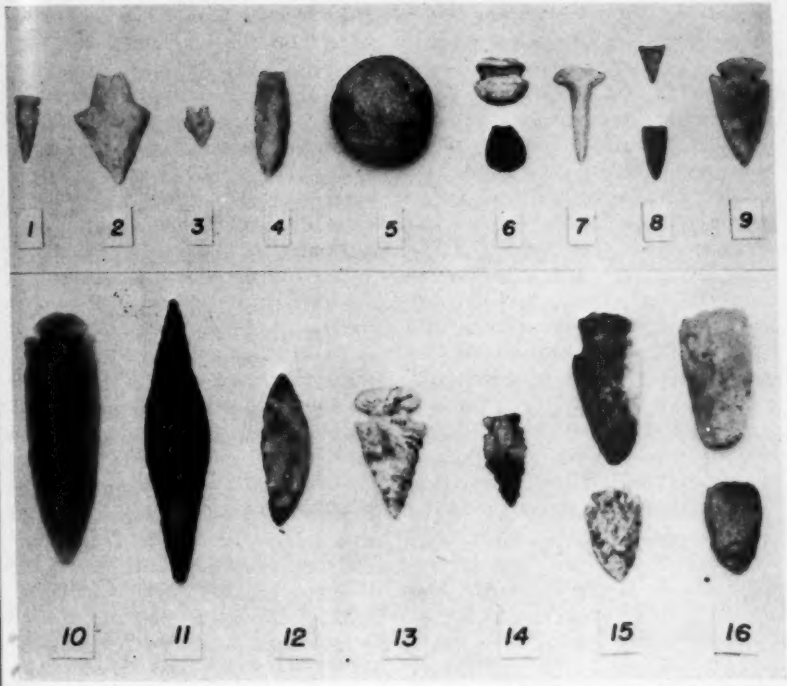

PLATE I.—Artifacts representative of groups described in text.

average measurements are about 1 15/16″ x 4/16″ x 1 3/16″. Workmanship is very good in a few cases.

Group VII (fig. 7).—Drills are often thumb screw or plain heads and measure ¼″x2″x7/16″. Workmanship is good in most cases. A high percentage of drills are broken.

Group VIII (fig. 8).—Triangular projectile points are arranged according to a pattern designed by John W. Griffin, a graduate student at the University of Chicago. An article explaining his pattern was published in the April 1945 issue of the Journal of the Illinois State Archaeological Society. These points measure approximately ⅛″x11/16″ x 1 3/16″. The workmanship is good considering the small size of the pieces.

Group IX (fig. 9).—Convex based arrowheads measure 6/16″x 3″ x (1 7/16″ x 6/16″). The bases are usually nearly symmetrical.

Group X (figs. 10, 11, 12).—These are a mixed lot of possibly ceremonial pieces. The two larger pieces are slightly more than 5 inches long. The slender double-pointed piece is a gray spearhead. The other arrowhead is made of quartzite and exhibits excellent symmetry and workmanship. The smallest piece is a

willow-leaf celt 4 inches long and is finely worked with the entire perimeter a cutting edge.

Group XI (fig. 13).—Beveled-edge arrowheads are apparently all made by a right-handed person. They measure about 4/16″ thick x 2¼″ x 8/16″. The workmanship is fair to good.

Group XII (fig. 14).—Serrate-edge arrowheads are only fair in workmanship. The points or teeth along the edge are uneven in size and length. These pieces measure approximately 4/16″ in thickness x 2″ x (1 3/16″ x 3/16″).

Group XIII (fig. 15).—The colored arrowheads are about average in dimension and range from dull black, dull reddish brown, red, lustrous reddish brown, blue and white, to mottled blue and white.

Group XIV (fig. 16).—Broad flint celts are common chipped artifacts. Flint is among the materials longest in use in America for making stone tools. These tools measure on the average 6/16″ thick x 1 4/16″ x 1 14/16″. Much use destroys the symmetry of these pieces usually.

The Indian certainly had an eye for variety and beauty of colored materials in his flint artifacts as well as in his blankets and head dress. With only the beauty of nature for his educational background, his accomplishments, in their limited way, show as much genius as do the works of world-renowned artists and sculptors of past generations.

BOTANY

CHECK LIST OF FLESHY FUNGI COLLECTED IN WEST-CENTRAL ILLINOIS

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This paper is an outgrowth of a study made of the fungi in the vicinity of Western Illinois State College during the summer of 1951 from July 14 to August 17. The problem was suggested by Roy M. Sallee and Maurice Myers. As a result of the unusually heavy rainfall during the spring and early summer there was luxuriant fungus growth in the Argyle conservation area where the botany students were studying vegetation.

As far as the writer has been able to learn, no study has been made of the fungus plants of west-central Illinois. In 1917, McDougall (3) published a paper on the mushrooms in the eastern part of the state. Moffatt (4, 5) worked on the fungi of the Chicago area. A study of the fungi of the Great Lakes region was made by Graham (1) in 1944.

Of the seventy fungi identified by the writer in west-central Illinois, thirteen were reported by McDougall (3) in Champaign, Jackson, Union, and Wabash counties. They are: *Amanita verna* Fr., *Amanitopsis vaginata* Fr., *Cantharellus aurantiacus* Fr., *Cantharellus cibarius* Fr., *Clavaria cristata* Fr., *Collybia dryophila* Fr., *Collybia radicata* Fr., *Lactarius piperatus* Fr., *Lactarius volemus* Fr., *Mycena galericulata* Fr., *Peziza repanda* Wald., *Russula foetentula* Peck., and *Russula virescens* Fr.

All the fungi identified by the writer were reported by Graham (1) as occurring in the Great Lakes region with one exception, *Lycoperdon rimulatum* Pk. The present writer (2) however, reported this species in Ohio in an earlier paper. Of the remaining sixty-nine species of fungi, Graham lists five as "rare" and ten as "not common." The "rare" ones are: *Hydnum spongiosipes* Peck., *Lactarius affinis* Peck., *Marasmius Olneyi* Berk. and Curt., *Pluteolus reticulatus* Fr., and *Russula albidula* Peck., and the species listed as "not common" are: *Boletus auriporus* Peck., *Boletus indecisus* Peck., *Calvatia rubro-flava* (Cragin) Morg., *Clavaria aurantio-cinnabarina* Schw., *Craterellus pistillaris* Fr., *Hydnum repanda* L., *Irpex ambiguus* Peck., *Lactarius hygrophoroides* Burt. and Curt., *Russula pulverulenta* Peck., and *Russula tenuiceps* Kauffm.

The specimens collected in this study have been preserved and are in the herbarium at Western Illinois State College.

Acknowledgments

The writer wishes to thank Roy M. Sallee, Maurice Myers, and Mary A. Bennett for suggesting the study, for aid in collecting specimens, and for assistance in obtaining reference literature. She also wishes to express appreciation to Maurice Kellogg for assistance in collecting, identifying, and preserving the specimens.

Check List of Fleshy Fungi Collected in West-Central Illinois

ASCOMYCETES

Leotia lubrica (Scop.) Pers.
On ground in woods, Argyle area, McDonough Co.

Paxina subclavipes (Phill. & Ell.) Seav.
On ground in woods, Argyle area, McDonough Co.

Peziza repanda Wald.
On decayed wood, Argyle area, McDonough Co.

Sarcoscypha floccosa Schw.
On buried sticks, Argyle area, McDonough Co.

Xylaria digitata Grev.
On decayed log, Argyle area, McDonough Co.

BASIDIOMYCETES

Amanita muscaria Fr.
In woods, Argyle area, McDonough Co.

Amanita rubescens Fr.
In woods, Argyle area, McDonough Co.

Amanita verna Fr.
In woods, Spring Lake, McDonough Co.

Amanitopsis vaginata Fr.
In woods, Spring Lake, McDonough Co.

Boletus auriporus Peck.
In woods, Argyle area, McDonough Co.

Boletus castaneus Bull.
On ground in woods, Argyle area, McDonough Co.

Boletus cyanescens Bull.
In woods, Spring Lake, McDonough Co.

Boletus felleus Bull.
In woods, Argyle area, McDonough Co. Fruiting bodies very large, many as much as twelve inches in diameter.

Boletus indecisus Peck.
In woods, Argyle area, McDonough Co. Reported by Graham (1) as not common.

Boletus Russelli Frost
In woods, Argyle area, McDonough Co.

Calvatia rubro-flava (Cragin) Morg.
Growing on lawn, Havana. Reported by Graham (1) as not common.

Cantharellus aurantiacus Fr.
In woods, Argyle area, McDonough Co.

Cantharellus cibarius Fr.
In woods, Argyle area, McDonough Co.

Clavaria aurantio-cinnabarina Schw.
On ground in woods, Argyle area, McDonough Co. Reported by Graham (1) as not common.

Clavaria cristata Fr.
On ground in woods, Argyle area, McDonough Co.

Clavaria vermicularis Fr.
On ground in woods, Argyle area, McDonough Co.

Collybia dryophila Fr.
In woods, Argyle area, McDonough Co.

Collybia radicata Fr.
On ground in lawn, Macomb.

Collybia stipitaria Fr.
Growing among decayed leaves in woods, Argyle area, McDonough Co.

Cortinarius cinnamomeus Fr.
In woods, Spring Lake, McDonough Co.

Craterellus cornucipiodes (Pers.) L.
In woods growing on ground, Argyle area, McDonough Co. Reported by Graham (1) as rare.

Craterellus pistillaris Fr.
On ground in woods, Argyle area, McDonough Co. Graham (1) reports this species as not common.

Hydnum nyssae Berk. & Curt.
On dead branch, Argyle area, McDonough Co.

Hydnum repandum L.
On ground in woods, Argyle area, McDonough Co. Reported by Graham (1) as not common.

Hydnum spongiosipes Peck.
On ground in woods, Argyle area, McDonough Co. Graham (1) reports this species as rare.

Irpex ambiguus Peck.
On dead wild black cherry, Argyle area, McDonough Co. Reported by Graham (1) as not common.

Laccaria amethystina (Bolt.) Pk.
On ground in woods, Argyle area, McDonough Co.

Lactarius affinis Peck.
On ground in woods, Argyle area, McDonough Co. Reported by Graham (1) as rare.

Lactarius camphoratus Fr.
In damp woods, Argyle area, McDonough Co.

Lactarius corrugis Peck.
In woods, Argyle area, McDonough Co.

Lactarius hygrophoroides Burt. and Curt.
On ground in woods, Argyle area, McDonough Co. Reported by Graham (1) as not common.
Lactarius piperatus Fr.
On ground in woods, Argyle area, McDonough Co.
Lactarius volemus Fr.
On ground in woods, Argyle area, McDonough Co.
Lycoperdon curtisii Berk.
On ground in open woods, Argyle area, McDonough Co.
Lycoperdon rimulatum Pk.
On ground among moss, Argyle area, McDonough Co.
Marasmius delectans Morg.
Growing on dead leaves and sticks, Argyle area, McDonough Co.
Marasmius epiphyllus Fr.
Growing on mid-vein of decaying leaves, Argyle area, McDonough Co.
Marasmius Olneyi Berk. and Curt.
Growing on decaying leaves, Argyle area, McDonough Co. Graham (1) reports this species as rare.
Marasmius rotula Fr.
On decaying leaves and sticks, Argyle area, McDonough Co.
Marasmius siccus (Schw.) Fr.
On decaying leaves, Argyle area, McDonough Co.
Marasmius semihirtipes Peck.
In woods on decaying leaves and sticks, Argyle area, McDonough Co.
Mutinus elegans (Mont.) Ed. Fischer
In woods, Argyle area, McDonough Co.
Mycena galericulata Fr.
On decayed wood, Argyle area, McDonough Co.
Panus rudis Fr.
Growing on wood, Argyle area, McDonough Co.
Pluteolus reticulatus Fr.
In woods, Spring Lake, McDonough Co.
Polyporus Berkeleyi (Fr.) Berk.
On buried wood, Argyle area, McDonough Co.
Polyporus chioneus Fr.
On decayed log, Argyle area, McDonough Co.
Polyporus cinnabarinus (Jarq.) Fr.
On dead wood, Argyle area, McDonough Co.
Polyporus conchifer Schw.
On dead elm branches, Argyle area, McDonough Co.
Polyporus gilvus (Fr.) Schw.
On trunk of dead oak, Argyle area, McDonough Co.
Polyporus tulipiferous (Overh.) Schw.
On dead branches of wild cherry, Argyle area, McDonough Co.
Polyporus versicolor (L.) Fr.
On dead branches, Argyle area, McDonough Co.
Poria xantha Lind.
On log, Argyle area, McDonough Co.
Russula albibula Peck.
On ground in woods, Argyle area, McDonough Co. Reported by Graham (1) as rare.
Russula cyanoxantha Fr.
On ground in woods, Argyle area, McDonough Co.
Russula foetentula Peck.
On ground in woods, Argyle area, McDonough Co.
Russula nigricans Fr.
On ground in woods, Argyle area, McDonough Co. Entire fruiting body becomes black when bruised.
Russula pulverulenta Peck.
In open woods, Argyle area, McDonough Co. Reported by Graham (1) as not common.
Russula tenuiceps Kauffm.
On ground in woods, Argyle area, McDonough Co. Graham (1) reports this species as not common.
Russula virescens Fr.
On ground in woods, Argyle area, McDonough Co.
Schizophyllum commune Fr.
On dead branches, Argyle area, McDonough Co.
Stereum fasciatum Schw.
On logs in woods, Argyle area, McDonough Co.
Stereum rameale Schw.
On dead twigs, Argyle area, McDonough Co.
Strobilomyces strobilaceus Berk.
On ground in open woods, Argyle area, McDonough Co.
Thelephora fimbriata Schw.
Incrusting small plants in damp places, Argyle area, McDonough Co.

Summary

This is an initial report of the fleshy fungi of west-central Illinois. Owing to the unusually heavy rainfall during the spring and summer of 1951, the fungus growth in this area was very luxuriant. The work of collecting, identifying, and pre-

serving the specimens of fungi was carried on during the period of July 14 to August 17, 1951, at Western Illinois State College. Most of the collections were made in the wooded area of the Argyle conservation park.

In this study seventy species of fungi were identified, five of which were Ascomycetes and sixty-five were Basidiomycetes. The former group includes one species each of the genera *Leotia, Paxina, Peziza, Sarcoscypha,* and *Xylaria.* The distribution of the species of the Basidiomycetes by genera is as follows: *Amanita* 3; *Amanitopsis* 1; *Boletus* 6; *Calvatia* 1; *Cantharellus* 2; *Clavaria* 3; *Collybia* 3; *Cortinarius* 1; *Craterellus* 2; *Hydnum* 3; *Irpex* 1; *Laccaria* 1; *Lactarius* 6; *Lycoperdon* 2; *Marasmius* 6; *Mutinus* 1; *Mycena* 1; *Panus* 1; *Pluteolus* 1; *Polyporus* 7; *Poria* 1; *Russula* 7; *Schizophyllum* 1; *Stereum* 2; *Strobilomyces* 1; and *Thelephora* 1.

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INITIAL REPORT ON THE MOSSES OF McDONOUGH COUNTY, ILLINOIS

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McDonough County is located in the west central part of Illinois. It has an average elevation of 690 feet and the average rainfall is 34.76 inches. The principal vegetation-types are upland timber, upland prairie, and bottom land.

Myers and Wright (1948) reported on the original and present vegetation of McDonough County but did not include the bryophytes. At the suggestion of Dr. Myers a collection of mosses was started.

Clay pits, formed by a series of excavations northeast of Macomb, were the chief collecting grounds. This area is rich in bryophytes growing in contrasting habitats. *Leptodictyum trichopodium* grows at the water's edge, *Dicranella heteromalla* grows on the underside of sandstone overhanging the water, *Entodon seductrix* and *Bryum cuspidatum* are found on exposed sandstone, *Ceratodon purpureus* is found on top of the clay ridges in full sunshine. Specimens were also collected at Spring Lake, Argyle Lake, and Bushnell prairie on lawns and trees.

Packets of the mosses are deposited in duplicate in the Western Illinois State College herbarium and in the author's collection. All of the specimens were checked by H. S. Conard.

The author wishes to express her thanks to Dr. Conard for help in classification, and to R. M. Myers and others who helped in collecting the mosses.

POLYTRICHACEAE
Atrichum angustatum (Brid.) Bry. Eur. B.S.G.

DITRICHACEAE
Ceratodon purpureus (Hedw.) Brid.

DICRANACEAE
Dicranella heteromalla (Hedw.) Schimp.

POTTIACEAE
Weisia controversa Hedw.

FUNARIACEAE
Funaria hygrometrica Hedw.
Physcomitrium turbinatum (Michx.) Brid.

BRYACEAE
Bryum argenteum Hedw.
Bryum cuspidatum (B.S.G.) Schimp.

MNIACEAE
Mnium cuspidatum Hedw.
Mnium medium B.S.G.

LESKEACEAE
Leska gracilescens Hedw.

HYPNACEAE
Amblystegium varium var. ovatum Grout
Brachythecium salebrosum B.S.G.
Campylium hispidulum (Brid.) Mitt.
Entodon seductrix (Hedw.) C. Muell.
Eurhynchium serrulatum (Hedw.) Kindb.
Leptodictyum trichopodium (Schultz) Warnst.

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GROWTH OF MANAGED EASTERN WHITE PINE PLANTATION IN NORTHERN ILLINOIS

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This is an interim report of a long-time study on an eastern white pine plantation at Sinnissippi Forest, Ogle County, which lies in north-central Illinois. The object was to determine tree growth and cultural practices best suited to the management of white pine for timber and other forest products. Four one-quarter acre permanent growth-study plots were established in a 16-acre stand of 34-year-old white pine in 1941. Prior to this time, all trees had been pruned to a height of about 15 feet, but the stand had never been thinned.

The first thinning was made in 1941. About 225 well-formed, vigorous trees per acre were selected and designated as crop trees. These crop trees were then pruned to a height of 17 feet. Two additional thinnings were made in 1946 and 1951. The details of these studies may be found in two previous publications (3, 5). The plantation is on light sandy soil, most of which is classed as dune sand by the University of Illinois soil survey (8).

Sinnissippi Forest

Sinnissippi Forest comprises 2,300 acres of native woodland and pine plantations and is operated by Dr. and Mrs. C. Phillip Miller. The Forest maintains a sawmill and a semi-commercial treating plant for the cold-soak treatment of pine fence posts (4). The smaller trees obtained from the thinnings were cut into 7-foot fence posts and the larger trees were sawn into lumber. These products were sold at retail by Sinnissippi Forest.

The average annual precipitation for Ogle County is approximately 34 inches and there are about 160 frost-free days during the growing season (6). Temperatures recorded during the past 54 years at Dixon, Illinois, 15 miles to the south, averaged 49.1°F. (6).

Stand and Stocking Data

Table 1 presents stand and stocking data for three measurements made at the ages of 34, 39, and 44 years. Volume tables presented in Harvard Forest Bulletin 13 were used to calculate the cubic and board-foot volumes shown in table 1; however, they exceeded the utilization standards practiced at Sinnissippi Forest. The stand density index is based on the number of trees per acre and their average diameter (7).

Thinning Yields

Yields of forest products and their values are given in table 2 for three thinnings made in 1941, 1946, and 1951. The monetary value of the forest products was their sale value at Sinnissippi Forest. A total gross return of $1,153.95 per acre was obtained from the three thinnings. The returns include, in addition to stumpage values, the profit from cutting, sawing, treating, and marketing the forest products. Previous studies (5) showed average net stumpage returns of approximately $100 per acre for the 1941 and 1946 thinnings.

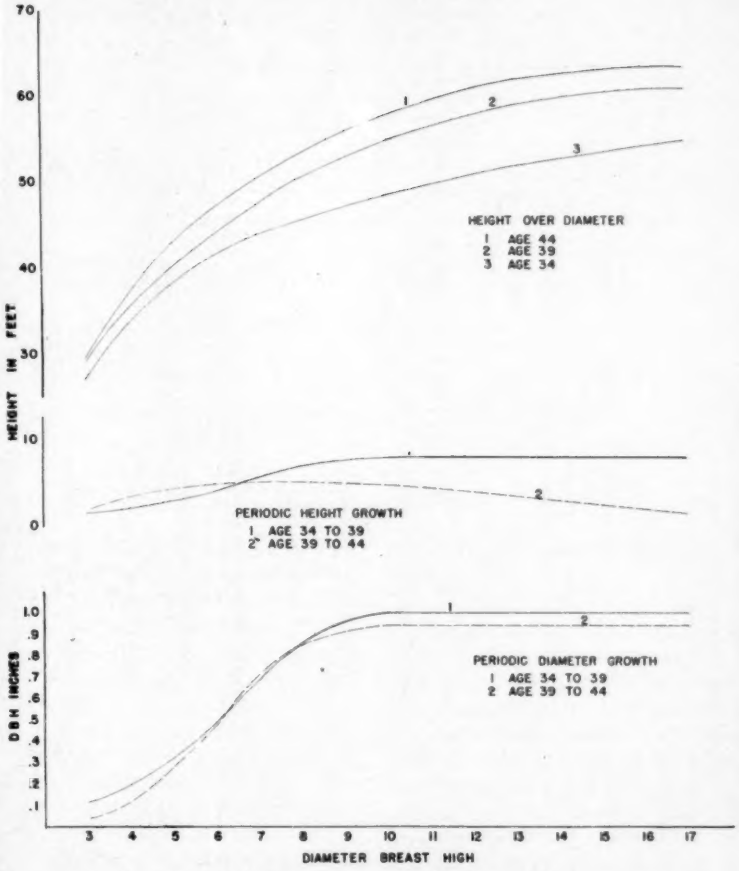

FIG. 1.—Curves of height over-diameter, periodic height growth, and periodic diameter growth.

GROWTH DATA

Figure 1 presents the height-diameter curves for the stand at ages 34, 39, and 44. Periodic height and diameter growth curves are also presented. Additional growth data appear in table 1. The dominant and codominant trees increased their diameter 0.2 inch annually or approximately 1 inch for each 5-year period from age 34 to 44. The total height growth for the 5-year period from age 34 to 39 was considerably greater than it was for the 5-year period from age 39 to 44. Based on present information, it appears that the mean annual growth has reached its point of culmination or will do so in the next 10 years.

The site index declined from 72

TABLE 1.—COMBINED DATA FOR FOUR ONE-QUARTER ACRE PLOTS

Eastern white-pine thinning and pruning plots

Sinnissippi Forest, Ogle County

Age	Trees per acre	Basal area	Av. height		Av. D. B. H.			Diam. range	Stand density	Volume per acre[a]	
			All trees	Dom. and codom.	Site index	All trees	Dom. and codom.			Trees 2″ and over	Trees 8″ and over
Years	No.	Sq. ft.	Ft.	Ft.	Ft.	In.	In.	In.	index	Cu. ft.	Bd. ft.
					Stand before thinning						
34	636	181	42	46	72	7.2	8.2	3–15	375	3,942	13,665
					Material removed in thinning						
34	148	38	40	..	..	6.9	....	3–12	...	821	2,742
					Stand after thinning						
34	488	143	43	46	72	7.3	8.2	4–15	294	3,121	10,923
					Stand before thinning						
39	452	161	49	53	70	8.2	8.9	3–16	329	3,937	17,869
					Material removed in thinning						
39	132	30	44	..	..	6.5	....	3–14	...	683	1,746
					Stand after thinning						
39	320	131	51	53	70	8.7	8.9	4–16	256	3,254	16,123
					Stand before thinning						
44	319	156	56	58	67	9.5	10.2	4–17	293	4,107	22,410
					Material removed in thinning						
44	85	30	52	..	..	8.0	....	4–13	...	760	3,112
					Stand after thinning						
44	234	126	57	58	67	10.0	10.2	5–17	234	3,347	19,298

TABLE 2.—PERIODIC THINNING YIELDS AND RETURNS FROM ONE ACRE OF EASTERN WHITE PINE

(Based on Four ¼-Acre Plots)

Age 34—1941		
392 posts[a] @ 55c	$215.60	
1,634 bd. ft. @ $65 per M	106.21	$321.81
Age 39—1946		
453 posts[a] @ 72c	$326.16	
861 bd. ft. @ $85 per M	73.18	399.34
Age 44—1951		
304 posts[b] @ 80c	$243.20	
1,580 bd. ft. @ $120 per M	189.60	432.80
Total yield and income from 3 thinnings 1,149 posts and 4,075 bd. ft		$1,153.95

a 7-foot posts with a minimum top D. I. B. of 3½ inches.
b 7-foot posts with a minimum top D. I. B. of 3 inches.
All board-foot measurements were based on ¼-inch International log rule.

feet at age 34 to 67 feet at age 44. Lorenz and Spaeth (2) have shown that most of the conifers growing on heavy prairie soil in central Illinois declined rapidly in height growth after reaching age 25 or 30 years, resulting in a decline in site index. This growth phenomenon for conifers, on the heavy prairie soils of central Illinois, was much more pronounced than that of the white pine stand at Sinnissippi Forest.

White Pines Forest State Park, which lies only 6 miles to the west, is the present southernmost native white pine stand in Illinois. The stand has maintained its growth fairly well with age. In 1941 the larger trees were approximately 100 years old, 26 inches in diameter, and 100 feet high.

The planting stock for the Sinnissippi stand was shipped in from Massachusetts, so the seed may have been of New England origin. If that were true, it would suggest the possibility of an improper seed source.

SUMMARY AND CONCLUSION

Growth and thinning studies begun in 1941 have been continued on four quarter-acre plots established in an eastern white pine plantation at Sinnissippi Forest. Thinnings made in 1941, 1946, and 1951 totaled 1149 fence posts and 4075 board feet of lumber which together yielded a gross return of $1,153.95. Net stumpage returns for the 1941 and 1946 thinnings averaged approximately $100 per acre each. These returns should encourage the planting of white pine in northern Illinois on soils not suited for agricultural crops. The site index declined from 72 feet at age 34 to 67 feet at age 44. Although this decline was gradual, it definitely points out the importance of establishing long-time growth patterns before any one species can be recommended for planting on a given site.

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THE BEHAVIOR OF OAK WILT IN SINNISSIPPI FOREST*

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The oak wilt disease, caused by the fungus *Chalara quericina* Henry, has been found in at least 18 states. The study of the mysterious dying of oaks was begun in Wisconsin in 1934. In Illinois the dying of oaks in the late 1930's was generally thought to be the delayed result of injuries suffered in the severe drouth years of 1934 and 1936. It now appears that the real cause may have been the oak wilt disease which was then unknown. The fact that dying trees were in patches and that trees in the red-oak group were particularly conspicuous supports this supposition.

The disease is now most prevalent in northern Illinois, although it has been found in isolated locations throughout the state. There is no reason to believe that it will be less damaging in central and southern Illinois.

Although work on the disease has been under way for a long time in Wisconsin and Iowa, it is only within the last two years that a large number of research workers have turned their attention to it. All phases of the nature and effects of the disease are now being studied. Pathologists and physiologists are studying the life history and behavior of the fungus and its hosts and the methods of dissemination of the pathogen. The transmission of the disease from one tree to another through root grafts has been established. It is thought to be the principal means by which an ever-widening circle of dead trees develops around the first infected tree in a specific location.

There is as yet no conclusive proof as to how the disease becomes established in trees which are not close enough to an infected tree to have established a root graft with it. The carrier may be wind, water, birds, insects, rodents, or some agent which has not been suspected. No one has as yet demonstrated that it is any of these agents. In attempts to control the disease, attention has been focused thus far on breaking the organic connection between the roots of the diseased tree and those of adjacent healthy trees. This may be done by trenching in the soil or by poisoning a ring of trees around an infection center. It has been reported that experiments in chemotherapy have yielded encouraging results.

In Illinois we are concerned about oak wilt disease because 5,832,000,000 board feet of our merchantable timber, or 56.4 percent of the total forest stand, is oak. Oaks are not only the most abundant species but, except for black walnut or tulip poplar, they are usually the most valuable. The oak volume in Illinois is divided almost equally between those which are most susceptible to the disease (the red-oak group) and those in which the disease develops more slowly (the white-oak group).

* The author gratefully acknowledges the cooperation of L. R. Tehon, Illinois State Natural History Survey, who arranged for funds from the National Oak Wilt Research Committee to finance the field observations, which were made by Theodore C. Curtin.

Sinnissippi Forest near Oregon, in the Rock River Valley, is typical of the upland oak forests of northern Illinois. It contains 1,600 acres of native timberland bearing a stand of 7 million board feet of timber, of which 90 percent is oak. Its management is directed by research foresters of the Illinois Agricultural Experiment Station. Because the Forest has been mapped in detail and every significant difference in site quality or stand composition has been segregated, this area affords a unique opportunity to study the behavior of oak wilt disease and to experiment with methods of control. Observation of the spread of oak wilt in this area has been under way for two years.

In the summer of 1950 the location of every tree showing symptoms of the disease, and of every dead tree which appeared to have died of the disease, was plotted on large scale maps. This was done by covering the area completely with strip transects. Each affected tree, whether dead or alive, was recorded by species, diameter, crown class, and probable date of death, if not living. The same procedure was followed twice in the summer of 1951, adding new locations or enlarging the affected area on the map wherever new diseased trees were found.

An analysis of the data leads to several interesting observations:

More than 100,000 board feet of merchantable timber have been killed. In the summer of 1951 trees containing more than 50 M board feet of timber showed the disease for the first time. Fifty-two percent of the oaks in Sinnissippi Forest are in the red-oak group and 48 percent are in the white-oak group (either *Quercus alba* or *Quercus macrocarpa*). Of the trees which have been attacked by oak wilt, more than 80 percent are in the red-oak group and less than 20 percent are white or bur oak. Since the forest is made up of almost equal numbers of trees in the red-oak and white-oak groups and the incidence of oak wilt disease is in ratio of more than four to one, these observations bear out the general belief that the red-oak group is more susceptible to wilt than the white-oak group. Within the red-oak group the red oak species (*Quercus rubra* L.) is more susceptible than black oak (*Quercus velutina* Lam.). Only 9.5 percent of the oaks in Sinnissippi Forest are red, but 23.5 percent of the trees affected by oak wilt are of this species; 42.8 percent of all the oaks are black and 56.9 percent of the trees affected by wilt are of this species.

Not only does the higher proportion of trees in the red oak group become infected, but also the disease progresses more rapidly in red oaks than in white oaks. In the first observations in July of 1951, symptoms were observed in many trees which did not show evidence of disease in 1950. At the time of the second examination, in August and September, 1951, red oaks that showed only symptoms at the first examination were dead, whereas the disease had progressed more slowly in the white oaks.

In forest areas, large trees are more likely than small ones to become infected. In other words, the ratio of infected trees to total trees, when compared by diameter classes, increases with increase in diameter.

This is apparent in a comparison of all oaks by diameter classes or in a comparison of individual species.

The data do not show any differences in the incidence of oak wilt with respect to site quality or environment which cannot be explained by the effect of the site quality or environment on the size of the trees and the composition of the stand. Any material change in site quality, whether it be due to a difference in soil, slope, aspect, or a combination of these, results in a change in stand composition. Frequently these changes are sufficiently great to justify classifying the stand as a different forest type. The red-oak type contains a predominance of the most susceptible species (red oak); 1.4 percent of all the trees in this type have been attacked by oak wilt. The black-oak type contains a predominance of black oak; 0.92 percent of the trees in this type have been affected. In the white-oak type only 0.35 percent of the oaks have been affected. In the mixed-oak type, which contains substanial proportions of red, black, and white oak, 0.95 percent of the trees have been attacked.

Observation of the spread of oak wilt in Sinnissippi Forest will be continued in the summer of 1952 in the same way that it was conducted in 1951. In selected compartments various experimental control measures will be undertaken. The Forest is intensively managed for timber production. Most of the 100,000 board feet of timber killed by the wilt has been harvested and used. Since many of the trees were cut soon after they died, this harvest may have affected the spread of the disease. Experiments will be designed to determine the nature of this effect.

THE RALPH EMERSON FLOWER RESERVE OF ROCKFORD COLLEGE

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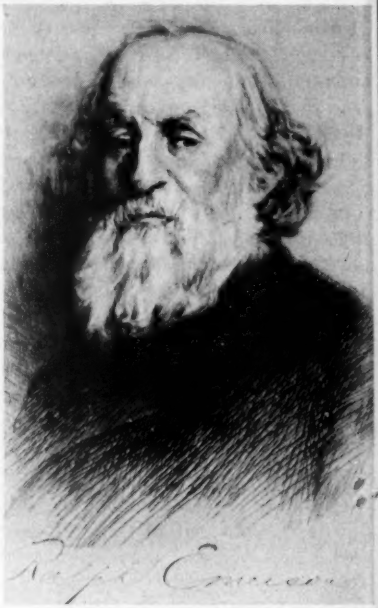
Rockford College, Rockford

The Ralph Emerson Flower Reserve was presented to Rockford College by Dora Emerson Wheeler (Mrs. William Morton Wheeler) in memory of her father, Ralph Emerson, May 3, 1947, at the Rockford College Centennial Convocation. On May 6, 1951, the dedication ceremony took place near a boulder on which there is now a bronze plate bearing the following inscription:

RALPH EMERSON FLOWER
PRESERVE
May 3, 1831-August 19, 1914
given in his memory to
Rockford College
by his daughter
Dora Emerson Wheeler
May 3, 1947

President Mary Ashby Cheek, members of the Board of Trustees, faculty, students, members of the Emerson family, and friends were present for the ceremony. Adaline Wheeler, Mrs. Wheeler's daughter, was the principal speaker.

Most of the tract, which is a little over five acres, is heavily wooded with many beautiful old trees and is an excellent example of the original oak-hickory forest. It is situated on the Rock River near its confluence with the Kishwaukee River, south of Rockford. Mrs. Wheeler designated that the reserve was to be used by the faculty and students of the college botany department for the study of the flora of the Rock River region and the advancement of knowledge in this field. In this way



she provided an outdoor laboratory for the students in the plant sciences. Following Mrs. Wheeler's wish that the whole college may enjoy the reserve a picnic is held there on May 3, the anniversary of Mr. Emerson's birth. It is at that time that the spring flowers are abundant and make an unusually fine display

Ralph Emerson came to Beloit, Wisconsin, from Andover, Massachusetts, at the age of 20, and a year later moved to Rockford. His brother Joseph taught at Beloit College for many years. Although he made his

great contribution in the industrial field and to its early development in Rockford, he was a versatile individual. He was long interested in education, which was quite natural as he came from a long line of clergymen and teachers.

He was always interested in the study of nature. His birthday was always celebrated by the family in some outdoor spot, and he spent many hours of his later life on this particular property. This love of nature was developed in him at an early age, for he wrote in a brief autobiography how he spent a great deal of time as a boy in Andover, Massachusetts, observing the country near his home. He tells us that "there was not a rock of any size, a berry patch, a little nook where any peculiar flower grew or any strange tree or bush for miles around with which I was not familiar. I could find flowers among those hills . . . swamps that probably not one in three hundred of the present inhabitants dreams exists there."

The boulder used as a marker for the reserve has an interesting history. Although Emerson fully appreciated the beauties of his adopted Illinois, he sometimes became homesick for New England. Finally he had two carloads of boulders sent from New England. One of these much-travelled boulders is now the marker for the preserve.

This love of the natural world he instilled in his children, and they in their varied ways have shown their appreciation of his teaching. To Mrs. Wheeler, with her childhood recollection of the glories of the wild flowers around Rockford and the May third family picnics in the lovely Illinois countryside, this memorial to her father seemed most fitting. The idea of establishing a wild flower reserve met with the hearty approval of Mrs. Wheeler's nephew and niece, Mr. and Mrs. Edward C. Hinchliff, without whose wholehearted cooperation it would not have been possible to establish this memorial.

As Miss Wheeler said at the time of the dedication, "This project is primarily for the serious study of botany . . . the possible touchstone to research and work in this line, together with an appreciation of existing plant material. Secondly, it is a means, in a small but real sense of the necessity of conservation in one of its more appealing and easily comprehended aspects by everyone who has any conception of beauty and fitness. Thirdly, this reserve can serve those who need to rebuild these inner springs of energy and well-being with fine peace and solace which nature in some of its varied manifestations can give to those who seek and find in her the means to carry on in these troubled times. Ralph Emerson saw not only the beauty in nature, but he also drew from this association the strength to go ever forward and carry the heavy responsibilities which he bore so ably throughout a long and arduous life."

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A MESOPHYTIC FOREST ON THE UPLAND PRAIRIE

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This study resulted from an interest in an oak-hickory-elm-ash-beech-maple-linden forest type on the upland prairie in east-central Illinois. A unique feature of this woods is a number of quite sizable American beech trees.

The land which includes this woods was purchased in 1910 from the Augustus family by the Foley family of Paris, Illinois. The Augustus family obtained it as an original land grant in 1831. When the Foleys bought this tract in 1910 much of the land which is now north of Route 16 as well as south and much of the crop land east of the woods was forest. Since the Foley people have owned the land they have been using the wood for lumber. The area is now known locally as Foley's Woods and is in R. 12 W., T. 12 N., S. part sec. 24, N. part sec. 25; it is 6 9/10 miles east of Kansas, Illinois, on Route 16, and the northwest corner of the woods is about ⅛ mile south of this point on Route 16. The woods is a rectangle one quarter of a mile wide and nearly three quarters of a mile long. It has a small area of cut-over, bushy, second growth extending out from its northeast and northwest corners. These second growth areas were not considered in the study. Only plants found in the more mature forest area were identified. A creek running through the northwest corner of the woods has built a small flood plain. A drainage ditch near the center of the length of the woods drains the fields to the east. It runs almost to the west side of the woods where it turns north and then runs out through a grass and weed-covered open area.

Method of Analysis

Essentially the work was divided into two parts. One part was a taxonomic study, the other an ecological examination. The taxonomic study consisted of an attempt to name all species of vascular plants found in the woods, including pteridophytes. This work included collecting and naming the herbaceous plants, and simply making a list of the woody plants. Herbaceous plants were named by use of floral keys and herbarium specimens. Many of the herbaceous plants have been mounted and are in the herbarium of Eastern Illinois State College. The woody plants were named by observation of their v e g e t a t i v e characteristics. Regular trips were made to the woods to collect plants for identification from April through October 1951. The plants were taken to the herbarium of Eastern Illinois State College where they were keyed, usually while the plants were still fresh, then dried and mounted.

The ecological study consisted of a statistical examination of the forest type of the woods. Thirty quadrats, 100 square meters or ten meters on each side, were laid out in the woods. To get a good representation of the woods, three imaginary lines were drawn along the length of the woods; one about sixty yards in from the west side of the woods, another about sixty yards in from the east side of

the woods, and one through the middle. The quadrats were laid out along these imaginary lines, each one hundred thirty-seven steps apart. This number was picked because arranging the quadrats that far apart would make ten quadrats cover the full length of the woods. After each quadrat was laid out, the trees within its bounds were listed as to size, kind, and number. The size classifications are as follows:

0 Seedlings
1 Transgressives — 1-3 inches in diameter
2 Understory—3-12 inches in diameter
3 Overstory—over 12 inches in diameter

Basal areas were determined for the trees of the number 2 and 3 classifications. Because, ecologically speaking, forest types are thought of in terms of beech-maple climax, oak-hickory climax, mixed mesophytic climax, etc., all of the oak trees were considered together in making the calculations for the study, although six different species are found in the woods. For the same reason all the hickories were considered together, even though there are three and possibly four species in this woods. In like manner, elms were grouped together, and the maples were grouped together.

Ecological Survey

Although in 30 quadrats there are only 22 oak trees, they have a basal area of 5,068 sq. in. This is larger than the basal area recorded for any of the other trees in the 30 quadrats. There are 41 hickories to be found in the 30 quadrats which have a basal area of 4,170 sq. in. This is the second highest basal area found. These two basal areas are much above the rest, the next highest being 1,884 sq. in. for 204 elms. More maple trees were found in these 30 quadrats than any other tree, there being 571. The basal area for these is 1,156 sq. in. The beech, which seems significant because of its appearance in this area, was found 15 times in the thirty quadrats; and has a basal area of 920 sq. in. Other trees of significant size are 20 basswoods having a basal area of 413 sq. in. and 58 ashes with a basal area of 975 sq. in. Although only seven hackberries were found, four of these were large, making a basal area of 827. In the 30 quadrats there was one large sycamore which had a basal area of 540 sq. in. (table 1).

These data show that the oaks and hickories, although few in number are large in size, indicating that in the past the woods was probably an oak-hickory climax. The history of the woods supports the theory that the forest type has been an oak-hickory climax. In 1921 and 1925 some walnut trees were cut for lumber. In 1935 a small amount of ash was cut. In 1938 some 7000 board feet of elm was taken from the woods. Thirty thousand board feet of oak were taken out in 1941, while in 1942, 67,000 board feet of oak, hickory, and walnut were cut. Again in 1948, 40,000 board feet of oak lumber were harvested. Of course the cutting of so much oak and hickory was conducive to the growth and development of the small, but more mesophytic forest climax trees which were present such as beech, maple, elm, hackberry, ash, and basswood. A factor which supports the assump-

TABLE 1.—DATA COLLECTED IN THIRTY QUADRATS RUN IN FOLEY'S WOODS

Name of tree	Basal area	No. of trees found in 30 quadrats	No. of quadrats occupied	Size classes encountered
Ash	875	58	22	0-1-2-3
Basswood	413	20	12	0-1-3
Bladdernut	....	307	6	0-1
Blue beech	13	14	5	0-1-2
Dogwood	....	1	1	0
Elms	1884	204	28	0-1-2-3
Hackberry	827	7	5	0-3
Hickory	4170	41	16	0-1-2-3
Oaks	5068	22	10	0-1-2-3
Sycamore	540	1	1	3
Walnut	58	2	1	0-2
Maples	1156	571	30	0-1-2-3
Beech	920	15	10	0-1-2-3
Mulberry	68	26	16	0-1-2
Redbud	151	14	5	0-1-2
Sassafras	104	8	5	0-1-2
Pawpaw	....	105	5	0-1
Wahoo	....	4	3	0-1
Cherry	....	2	2	0
Totals	16247	1422	173	

Trees found in Foley's Woods which did not occur in the thirty quadrats: Ironwood, Honey Locust, Kentucky Coffee Tree, Hawthorn.

tion that the woods is now a mixed mesophytic climax is the existence in the woods of many plants associated with a wetter, more mesophytic forest type. For instance 307 small bladdernut trees were found in the 30 quadrats, and also 105 young pawpaw trees. The spice bush, basswood, hackberry, walnut, mulberry, and Kentucky coffee trees also occur in the woods. These plants are usually found in central Illinois only on the flood plain of a stream. The conclusion is then that because of lumbering and natural succession the woods has changed from an oak-hickory climax to a mixed mesophytic climax.

Taxonomic Survey

The regular collecting trips made from April through October of 1951 have resulted in a list of 123 species. These together with those added from the list made by R. E. Evers of the Illinois Natural History Survey make a total of 151 species representing 60 families. The nomenclature used is that followed by G. N. Jones in his *Flora of Illinois*.

The occurrence of American beech (*Fagus grandifolia*), golden seal (*Hydrastis canadensis*), and the nodding trillium (*Trillium gleasoni*) in this woods are the most unusual records for this part of the state.

The taxonomic list is as follows:

Acanthaceae
Ruellia strepens, Smooth Ruellia
Aceraceae
Acer saccharum, Sugar Maple
A. saccharinum, Soft Maple
Anacardiaceae
Rhus radicans, Poison Ivy
Annonaceae
Asimina triloba, Pawpaw
Araceae
Arisaema triphyllum, Jack-in-the-Pulpit
A. dracontium, Green Dragon
Aristolochiaceae
Asarum canadense, Wild Ginger
Balsaminaceae
Impatiens biflora, Spotted Touch-Me-Not
Berberidaceae
Caulophyllum thalictroides, Blue Cohosh
Podophyllum peltatum, May Apple
Berberis thunbergii, Japanese Barberry
Betulaceae
Corylus americana, Hazel
Carpinus caroliniana, Blue Beech
Ostrya virginiana, Ironwood
*Bignoniaceae
**Campsis radicans*
*Boraginaceae
**Hackelia virginiana*
Campanulaceae
Campanula americana, American Bellflower
Caprifoliaceae
Sambucus canadensis, Common Elder
Caryophyllaceae
Silene stellata, Starry Campion
Celastraceae
Euonymus atropurpureus, Wahoo
Celastrus scandens, Bittersweet
Commelinaceae
Tradescantia virginiana, Spiderwort
T. subaspera, Spiderwort
Compositae
Erigeron annuus, White Top
Lactuca canadensis, Wild Lettuce
Prenanthes crepidinea, Lion's Foot
Eupatorium rugosum, White Snakeroot
E. purpureum, Joe-pye Weed
Ambrosia trifida, Great Ragweed
**Solidago ulmifolia*
Cornaceae
Cornus florida, Flowering Dogwood
Cruciferae
Cardamine bulbosa, Spring Cress
Dentaria laciniata, Toothwort
Iodanthus pinnatifidus
Cyperaceae
Carex squarrosa, Sedge
**C. grisea*
**C. hirtifolia*
**C. rosea*
Fagaceae
Fagus grandifolia, American Beech
Quercus imbricaria, Shingle Oak
Q. borealis, Red Oak
Q. velutina, Black Oak
Q. alba, White Oak
Q. macrocarpa, Bur Oak
Q. muhlenbergii, Chestnut Oak
Fumariaceae
Dicentra cucullaria, Dutchman's Breeches
Geraniaceae
Geranium maculatum, Cranesbill
Gramineae
Poa annua, Low Spear Grass
**Bromus purgans*
**Cinna arundinacea*
**Elymus villosus*
**Festuca obtusa*
Grossulariacea
Ribes sp., Gooseberry
**R. missouriense*
Hydrangeaceae
Hydrangea arborescens, Wild Hydrangea
Hydrophyllaceae
Hydrophyllum appendiculatum, Waterleaf
H. virginianum, Waterleaf
Juglandaceae
Juglans nigra, Black Walnut
Carya ovata, Shagbark Hickory
C. cordiformis, Bitternut Hickory
C. glabra, Pignut Hickory
**C. laciniosa*

Labiatae
Blephilia hirsuta
Prunella vulgaris, Selfheal
Scutellaria ovata, Skullcap
Glecoma hederacea, Ground Ivy
**Agastache nepetoides*
Lauraceae
Lindera benzoin, Spice Bush
Sassafras albidum, Sassafras
Leguminosae
Cercis canadensis, Redbud
Gleditsia triacanthos, Honey Locust
Gymnocladus dioica, Kentucky Coffee Tree
Desmodium nudiflorum, Tick-clover
**Trifolium repens*
Liliaceae
Trillium recurvatum, Wake Robin
T. gleasoni, Nodding Trillium
Smilax hispida, Greenbrier
S. herbacea, Carrion Flower
Erythronium albidum, White Dog's Tooth Violet
Smilacina racemosa, False Solomon's Seal
Uvularia grandiflora, Bellwort
*Limnanthaceae
**Floerkea proserpinacoides*
*Lobeliaceae
**Lobelia inflata*
Menispermaceae
Menispermum canadense, Moonseed Vine
Moraceae
Morus alba, White Mulberry
**M. rubra*
Oleaceae
Fraxinus americana, White Ash
Onagraceae
Circaea latifolia, Enchanter's Nightshade
Ophioglossaceae
Botrychium virginianum, Rattlesnake Fern
Oxalidaceae
Oxalis cymosa, Wood-sorrel
Papaveraceae
Sanguinaria canadensis, Bloodroot
Phrymaceae
Phryma leptostachya, Lopseed
Phytolaccaceae
Phytolacca americana, Pokeberry
Platanaceae
Platanus occidentalis, Sycamore
Polemoniaceae
Phlox divaricata, Blue Phlox
Polemonium reptans, Jacobs Ladder
Polygonaceae
Polygonum convolvulus, Black Bindweed
**P. hydropiper*
Polypodiaceae
Polystichum acrostichoides, Christmas Fern
Onoclea sensibilis, Sensitive Fern
Adiantum pedatum, Maidenhair Fern
Cystopteris fragilis, Bladder Fern
Dryopteris phegopteris, Beech Fern
Portulacaceae
Claytonia virginica, Spring Beauty
Primulaceae
Lysimachia lanceolate, Loosestrife
**L. ciliata*
**Samolus parviflorus*
Ranunculaceae
Isopyrum biternatum, False Rue Anemone
Ranunculus abortivus, Small Flowering Buttercup
R. septentrionalis, Swamp Buttercup
Actaea alba, White Baneberry
Delphinium tricorne, Larkspur
Ranunculus recurvatus, Hooked Crowfoot
Hepatica acutiloba
Rosaceae
Geum vernum, Spring Avens
G. canadense, White Avens
Agrimonia pubescens, Agrimony
**A. gryposepala*
Prunus pennsylvanica, Wild Black Cherry
Rubus sp., Raspberry
Crataegus spp., Hawthorn
**C. crusgalli*
**C. mollis*
**Rosa setigera*
Rubiaceae
Galium asprellum, Rough Bedstraw
G. triflorum, Sweet-scented Bedstraw
G. concinnum
G. circaezans, Wild-licorice
**G. obtusum*
Scrophulariaceae
Mimulus alatus, Monkey Flower
Staphyleaceae
Staphylea trifolia, American Bladdernut
Tiliaceae
Tilia americana, American Linden
Ulmaceae
Ulmus americana, American Elm
U. fulva, Slippery Elm
Celtis occidentalis, Hackberry
Umbelliferae
Osmorhiza claytoni, Sweet Cicely
Sanicula gregaria, Black Snakeroot
**S. canadensis*
Cryptotaenia canadensis, Honewort
Erigenia bulbosa, Harbinger-of-Spring
Urticaceae
Pilea pumila, Clearweed
Laportea canadensis, Wood Nettle
**Parietaria pennsylvanica*
Violaceae
Viola striata, Cream Violet
V. eriocarpa, Yellow Violet

*V. *papilionacea*
*V. *sororia*
Vitaceae
Vitis sp., Grapevine
*V. *aestivalis*
Parthenocissus quinquefolia, Virginia Creeper

* Plants collected from the Foley's Woods area by Robert Evers of the Illinois Natural History Survey, which were not incorporated into the original list of the author.

Summary

Located 6 9/10 miles east of Kansas, Illinois, Foley's Woods includes approximately 120 acres of mature forest. The woods is nearly surrounded by upland prairie farm land.

Regular collecting trips were made to the woods from April to October of 1951. From the plants collected on these trips, 123 species have been identified to date. These species represent 56 families. The most unusual records for this part of the state are American beech (*Fagus grandifolia*), golden seal (*Hydrastis canadensis*), and the nodding trillium (*Trillium gleasoni*).

The oaks and hickories on a whole are the larger trees in the woods, although there are fewer of them, indicating that this woods has at one time been an oak-hickory climax forest type. The presence of bladdernut, pawpaw, spice bush, Kentucky coffee tree, mulberry, walnut, hackberry, and basswood species usually associated with the wetter more mesophytic forest type, indicates that this woods is now a mixed-mesophytic forest type. Another significant thing is that a great many American beech trees, which are not found in other forested areas of central Illinois, are present in this woods. Some of these are quite sizable, being almost as large as the big beech trees of the beech-maple climax forests in Indiana and Michigan. Considerable lumbering during which much oak and some hickory were taken out of the woods has allowed the growth and development of the more mesophytic tree species. This has hastened the transition from the oak-hickory climax to the mixed mesophytic climax.

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CHEMISTRY

THE RELATIVE ABUNDANCE OF THE ELEMENTS

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Interest in the elemental composition of his surroundings must have developed in man almost as soon as the concept of elementary forms of matter was originated. Empedocles (450 B. C.) is supposed to have been the first to propose the four elements air, earth, fire and water; he attempted to state the composition of flesh and bones in terms of these elements. But accurate methods of chemical analysis had to come before the quantitative study of the rocks which make up the earth's crust. After Bunsen turned his attention from organic to inorganic chemistry he developed an interest in petrology, studying in particular the composition of rocks he had observed in Iceland. A table derived from Bunsen's data of the average composition of the solid crust of the earth was published in Newth's *Inorganic Chemistry*:

Relative abundance of the elements

	Percent	
O	44.0—	47.7
Si	22.8—	36.2
Al	9.9—	6.1
Fe	9.9—	2.4
Ca	6.6—	0.9
Mg	2.7—	0.1
Na	2.4—	2.5
K	1.7—	3.1
	100.0	100.0

Many other determinations of the elemental composition of the earth's crust have been made since the time of Bunsen, but one of the most comprehensive was that of F. W. Clarke and H. S. Washington published in 1924 (1). Their figures, which were based on some 5,000 "superior" analyses selected from more than 8,000 analyses of igneous rocks, have been widely quoted in chemistry textbooks. The rocks came from every continent and major island group. Clarke and Washington assumed that the composition of the crust to a depth of 10 miles below sea level would not vary greatly from that of the volcanic outflows and other rock forms observable at the surface. The volume of matter involved, including the mean elevation above sea level, amounted to 1.6×10^9 cubic miles; matter had an average specific gravity of about 2.6. The surface layer was estimated to consist of 93 percent solid and 7 percent liquid, the atmosphere making up a scant 0.03 percent by weight. It was observed that the average composition of the lithosphere was very nearly the same as the composition of the igneous rocks alone. This is due to the great preponderance of the latter. The estimate given for the relative abundance of the rock types follows:

	Percent
Igneous	95
Sedimentary	5
Shale	4
Sandstone	0.75
Limestone	0.25

The metamorphic rocks were not included since their quantities were presumed to be too small to seriously modify the final averages. The adjusted figures as given by Clark (2) agree quite well with later figures by other investigators. They show 99.5 percent of the outer ten miles of the earth to be made up of eighteen elements as follows:

	Percent
Oxygen	49.20
Silicon	25.67
Aluminum	7.50
Iron	4.71
Calcium	3.39
Sodium	2.63
Potassium	2.40
Magnesium	1.93
Hydrogen	0.87
Titanium	0.58
Chlorine	0.19
Phosphorus	0.11
Manganese	0.09
Carbon	0.08
Sulfur	0.06
Barium	0.04
Nitrogen	0.03
Fluorine	0.03

The relative abundance of the elements in terms of the number of atoms can be derived by dividing the weight percentages by the atomic weights. When this is done the greatest differences are observed in the case of hydrogen and other light elements such as carbon and nitrogen. The first eighteen elements on this basis are shown below. The figures are derived from the data of Anderson published in 1942 (3).

	Relative no. of atoms $\times 10^{-5}$
Oxygen	3094
Hydrogen	863
Aluminum	278
Sodium	114
Calcium	84.6
Iron	84.1
Magnesium	79.3
Potassium	61.4
Titanium	12.1
Carbon	6.66
Chlorine	5.36
Phosphorus	3.87
Nitrogen	2.14
Sulfur	1.87
Manganese	1.64
Fluorine	1.42
Chromium	0.634

These are followed by lithium, vanadium, nickel, zinc, barium, zirconium, strontium, and copper, in that order.

The composition of the earth below the region of igneous rocks is largely speculative. Estimates of volume and mass of the earth lead to the conclusion that the density of the earth as a whole is considerably greater than the density of the surface rocks. The overall density appears to be 5.52 g./cm.^{3} whereas the density of granite and basalt are 2.75 and 3.3 g./cm.^{3} respectively. To account for this a region of much higher density must be assumed.

The composition of meteorites has led to the conclusion that an iron-nickel core is present in the earth. V. M. Goldschmidt proposed (4) a series of layers (fig. 1) which could have been formed by the cooling of a

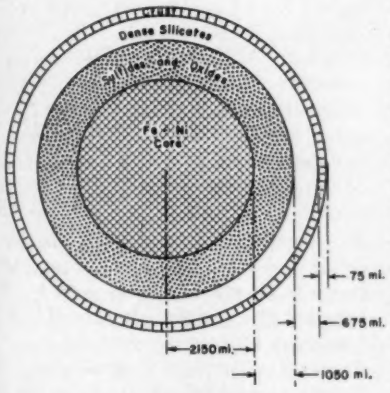

FIG. 1.—Layers formed by cooling of a gaseous or fused mass. (After V. M. Goldschmidt.)

gaseous or fused mass. The inner iron-nickel core has a radius of approximately 2150 miles. Above this is a layer of oxide and sulfide ores of density 5-6 g./cm.^{3} extending outward for another 1000 miles Surrounding this sulfide layer is a dense layer of highly compressed solid silicates having a density of 3.6-4 g./cm.^{3} This eclogitic layer extends to within 75 miles of the surface. Goldschmidt compares this system to the layers formed during the metallurgy of copper. The lower layer of metal is covered with a copper matte made up of metallic sulfides and above that floats a slag made up of silicates. The composition of the crust is thus determined by the ability of the slag or silicate layer to extract the various metals and oxides.

Goldschmidt believed that meteorites may have solidified with separation in a similar way but that the eclogitic layer was not possible because of insufficient pressure in small meteorites. There is some speculation that meteorites tend to lose their silicate shells while passing through the outer atmosphere of the earth. Maskelyne (5) proposed that the frictional heating of the meteorite due to its high velocity causes the shell to be heated to incandescence and to expand and fly away from the central mass with explosive violence. Thus the surface layer has been left as a trail of meteoric dust and only the core reaches the earth's surface. The composition of meteorites classes them as iron, stony, or carbonaceous metorites. The last class is very small, although it is possible that very few carbonaceous meteorites reach the earth's surface without being completely consumed by the oxygen in the atmosphere. The other two classes merge into one another. For instance the stony meteorites almost invariably contain nickel-iron. The almost total absence in meteorites of quartz and feldspars, the most common minerals in the earth's crust, is further evidence of the disintegration of the outer shell of the meteorite. An average of 318 analyses of iron meteorites gives 90.85 percent iron, 8.52 percent nickel and 0.59% cobalt which is in fair agreement with analyses of terrestrial iron found in Greenland.

It is apparent, then, that with such inadequate data on the composition of all but 0.1 percent of the radius of the earth it is difficult to arrive at an overall abundance ratio. Clarke (2) roughly estimates iron 67.2 percent, oxygen 12.8 percent, silicon 7 percent, and nickel 4 percent. The percentages of all the other elements are small.

The first adequate and complete tabulation of modern universal relative abundances was made by Goldschmidt (6) in 1938. His sources were principally analyses of meteoric composition and stellar spectra. Still more recently Brown (7) worked out new tables of stellar abundances of the lighter elements, meteoric abundances, cosmic abundances of the elements, and cosmic abundances of nuclear species. In general there is reasonably good agreement between the relative abundances determined in various regions of the universe. Terrestrial and meteoric composition differs from stellar principally in the more volatile elements hydrogen and the rare gases. Varia-

tions in the percentages of the light elements with atomic numbers 1 through 7 (including deuterium) are accounted for by the thermonuclear reactions between protons and the nuclei of the lightest elements of the periodic system. Gamow (8) postulates the following reactions as occurring successively as the temperature of a steller body heats up from 1 million to 20 million degrees:

$$_1D^2 + {}_1H^1 \rightarrow {}_2He^3 + \text{radiation}$$
$$_3Li^6 + {}_1H^1 \rightarrow {}_2He^4 + {}_2He^3$$
$$_3Li^7 + {}_1H^1 \rightarrow {}_2He^4 + {}_2He^4$$
$$_4Be^9 + {}_1H^1 \rightarrow {}_3Li^6 + {}_2He^4$$
$$_5B^{10} + {}_1H^1 \rightarrow {}_6C^{11} + \text{radiation}$$
$$_5B^{11} + {}_1H^1 \rightarrow 3({}_2He^4)$$

The processes of energy formation in the sun and other stellar bodies which have passed the 20 million degree temperature mark do not consume the lighter elements other than hydrogen if the carbon-nitrogen cycle of Bethe and Weizsäcker proposed in 1938 is correct. This cycle, which requires five million years, consists of the following six reactions in which four hydrogen atoms (protons) are converted into one helium atom with the evolution of two beta particles and three quanta of energy as gamma rays:

$$_6C^{12} + {}_1H^1 \rightarrow {}_7N^{13} + h\gamma \text{ (gamma ray)}$$
$$_7N^{13} \rightarrow {}_6C^{13} + e^+ \text{ (beta particle)}$$
$$_6C^{13} + {}_1H^1 \rightarrow {}_7N^{14} + h\gamma \text{ (gamma ray)}$$
$$_7N^{14} + {}_1H^1 \rightarrow {}_8O^{15} + h\gamma \text{ (gamma ray)}$$
$$_8O^{15} \rightarrow {}_7N^{15} + e^+ \text{ (beta particle)}$$
$$_7N^{15} + {}_1H^1 \rightarrow {}_6C^{12} + {}_2He^4$$

Having established that the relative abundance of the elements is very nearly uniform throughout the universe it becomes desirable to learn the rules controlling the abundances and the theoretical explanations of these rules. One of the first rules to be observed is that abundance decreases with either increasing atomic number or atomic mass. A plot of the logarithm of relative abundance vs. atomic number is given in fig. 2. The data are from Brown (7); the relative abundance is taken with respect to 10,000 atoms of silicon. An outstanding feature of the plot is the rapid decrease in abundance up to atomic number 45. From that point on the abundance is nearly constant.

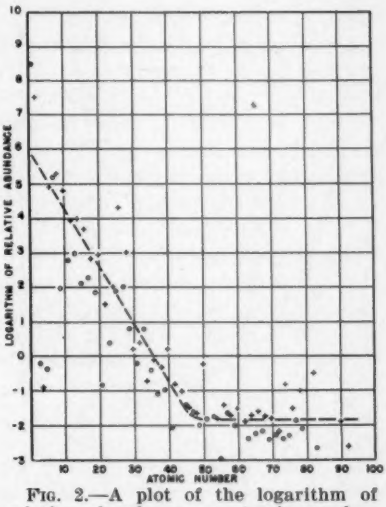

FIG. 2.—A plot of the logarithm of relative abundance vs. atomic number.

Another rule, which has long been observed, is the greater abundance of elements of even atomic number over those of odd atomic number immediately preceding or following. This is particularly noticeable if the elements of the transition groups are investigated. In fig. 3 the logarithm of the abundance is plotted against atomic number. The elements of the third, fourth, and fifth periods of the periodic chart are superimposed (with adjusted scale to bring the fourth and fifth period elements in line with those more

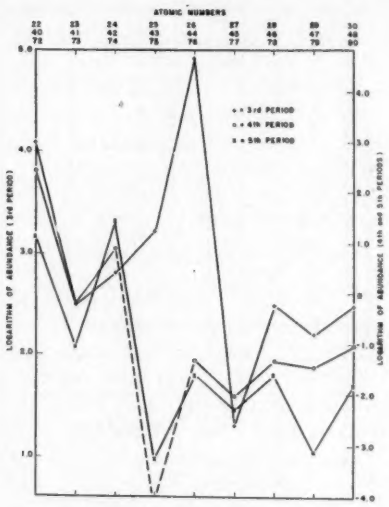
ATOMIC NUMBERS
22 23 24 25 26 27 28 29 30
40 41 42 43 44 45 46 47 48
72 73 74 75 76 77 78 79 80
• = 3rd PERIOD
○ = 4th PERIOD
× = 5th PERIOD
LOGARITHM OF ABUNDANCE (3rd PERIOD)
LOGARITHM OF ABUNDANCE (4th and 5th PERIODS)

FIG. 3.—Logarithm of abundance plotted against atomic number.

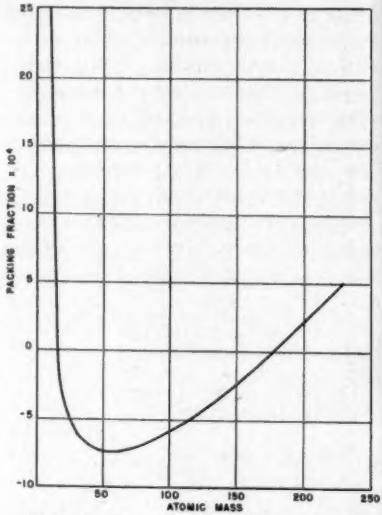

FIG. 4.—A plot of packing fraction against atomic mass.

abundant members of the third period). The data are those of J. S. Anderson (3). The abundances are derived from percentages by dividing by the atomic weights and multiplying by 10^8. It is observed that the values for manganese and iron are out of line. This "superabundance" of elements with masses in the neighborhood of 50 has been explained in terms of their low packing fractions. A plot of packing fraction against atomic mass (fig. 4) shows a minimum for elements with atomic masses of the same order as iron and manganese. Packing fraction is defined as the ratio of mass excess to mass number.

Not only are atoms of even atomic number usually more abundant than those adjacent atoms of odd atomic number, but atoms of even mass number are commonly more abundant than atoms of mass number one greater or one less. In this connection it is interesting to note that of 40 elements of odd atomic number listed in isotope tables, 23 are believed to exist in only one isotopic form with odd mass numbers and 12 others show only two isotopes both having odd mass

$$\text{Packing fraction} = \frac{M - A}{A}$$

where M = actual mass of a particular isotope (equal to the sum of the masses of the protons and neutrons in the nucleus)

A = The mass number of the isotope (the whole number nearest to the actual mass)

For example, the packing fraction of oxygen is:

$$\frac{(8 \times 1.00812) + (8 \times 1.00893) - 16.00}{16.0000} = \frac{0.13640}{16.0000} = 00.008525$$

numbers. Of the remaining five (hydrogen, lithium, boron, nitrogen, and potassium) nitrogen is the only one whose principal isotope is of even mass (99.62% N^{14}) and potassium is the only one known to have three natural isotopes. The potassium isotope of even mass (0.012%) is radioactive.

On the other hand, the 43 atoms of even atomic number whose isotopic composition has been determined, show an average of slightly over 5 isotopes per atomic species. Furthermore, among these isotopes of even-numbered atoms, the ones of even mass number exceed those of odd mass number by 3:1 (166 to 56).

A partial explanation of these factors lies in the instability of atoms of uneven number. They may undergo three types of changes:

1. If the element has too little mass for its charge it will decay and liberate a positron.
   $Si^{27} \rightarrow Al^{27} + \beta^+$
2. If the element has too little charge for its mass it will liberate an electron on decay.
   $Si^{31} \rightarrow P^{31} + \beta^-$
3. The element may capture a K electron.
   $_{76}Os^{187} + \beta^- \rightarrow {}_{75}Re^{187}$
   (This was the first example of K-capture actually observed with a natural isotope.)

Furthermore, for a nucleus to be stable it must have less mass than the combined masses of any pair of nuclei resulting from its subdivision. This would account for the absence of nuclei with masses of 5 or 8 as well as the fact that stable nuclei with even mass number almost invariably have even atomic number. A nucleus with even mass number and odd atomic number usually has an atomic mass greater than one or both of its neighbors and may change into one of both by β-emission or K-capture.

As early as 1873 Clarke (9) indicated the probability that the elements were originally developed by a process of evolution from much simpler forms of matter, as is indicated by the progressive chemical complexity observed in passing from the nebulae through the hotter stars to the cold planets.

In 1930 Goldschmidt (10) proposed that the frequency of occurrence of each type of atom, which appears to be the same in all parts of the cosmos, is determined by properties of the nucleus.

One of the early theories to explain the origin and abundance of the elements was that of Sterne (11) who showed that it was possible to consider by statistical mechanics an assembly containing radiation, atomic nuclei, electrons and neutrons wherein all possible transmutations of the nuclei occur without the "annihilation" of any ultimate particles. He proposed that one could calculate the abundance of the various nuclei in such an assembly, provided it was in equilibrium, in terms of the atomic masses and packing fractions. Sterne believed that these equilibria were established inside of many or perhaps all stars. He concluded that if all nuclei are composed ultimately of electrons and protons then the most abundant element, when equilibrium is estab-

lished at densities between one and one million grams per cubic centimeter and at temperatures which are "not too high," would be the element of even mass number and smallest packing fraction.

Weizsäcker (12) and Chandrasekhar and Henrich (13) believed the equilibrium state represented by the observed abundance curve was determined by nuclear binding energies at some very high temperature and density. Gamow (14) disputes this on the ground that since binding energy is approximately a linear function of atomic weight a rapid exponential decrease of abundance through the entire natural sequence of elements would be required by the equilibrium theory. This could account for the abundance of the lighter elements (fig. 2) but would not account for the approximately constant abundance of the heavier elements. It is not possible to assume that heavy nuclei were formed at higher temperatures and their abundances "frozen" while lighter nuclei were being formed since at 10^{10} degrees K. and 10^6 g/cm^3 density nuclear transformations are mostly caused by the processes of absorption and re-evaporation of free neutrons.

Thus the rates should be essentially the same for light or heavy elements. Gamow further postulates that the conditions necessary for rapid nuclear reactions were existing only for a very short time, perhaps considerably shorter than the β-decay period of free neutrons (about one hour). If free neutrons were present in large quantities in the beginning of the expansion of the universe, the mean density and temperature of expanding matter must have dropped to comparatively low values before these neutrons had time to turn into protons. The neutrons forming this comparatively cold cloud were gradually coagulating into larger and larger neutral complexes which later turned into various atomic species by subsequent processes of β-emission. The decrease of relative abundance of the elements with increasing atomic mass must have been due to the longer time required for formation of heavy neutronic complexes by radiative capture. The high abundance of hydrogen must have resulted from the competition between the β-decay of original neutrons, resulting in inactive protons, and the coagulation process by which these neutrons were incorporated into heavier nuclei.

Alpher and Herman (15) carefully reviewed all aspects of the equilibrium theory of element formation. They point out that at high concentrations of neutrons the capture probabilities would increase as the material cooled, so that the distribution of elements would be radically changed, especially at high densities. In fact neutron capture reactions give important changes in element abundances even at densities of the order of 10^{-8}g/cm^3.

Alpher and Herman conclude that equilibrium theory applied to an assembly at a single density and temperature does not reproduce the observed relative abundance distribution and that a non-equilibrium theory of element formation requires the specification of detailed nuclear processes, principally successive radiative capture of neutrons with intervening β-disintegration. One difficulty of this

theory is the absence of nuclei with masses 5 and 8 and the high proportion of iron. The polyneutron fission theory which proposes, among other things, that the heavy nuclei are fragments resulting from the breakup of a "cold" nuclear fluid consisting primarily of neutrons does not seem consistent with the conditions which may have existed when the elements first came into being.

It is obvious from this brief discussion that the subject is far from being in a settled state. Part of the difficulty, as pointed out by Brown (16), is that the questions overlap so many of the scientific disciplines. In an age of increasing specialization in science, broad problems of this type cannot be solved rapidly.

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THE REMOVAL OF PHOSPHATE BY ZINC OXIDE

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The qualitative analysis for the alkaline earth metals requires the prior removal of phosphate ions, which is usually done during the course of the analysis of the ammonium sulfide precipitate. The methods most commonly used are the tin method, whereby the phosphate is removed in nitric acid solution by absorption on beta stannic acid formed from metallic tin, and the better known basic acetate method.

Treadwell and Hall[1] mention that in special cases, zinc oxide may be used, and Lundell and Hoffman[2] list zinc oxide as a means of complete precipitation of phosphorus. A study of the use of zinc oxide for the removal of phosphate in routine qualitative analysis is presented herewith.

Experimental

Since the basic acetate removal of phosphate depends on the regulation of the pH of the solution to the point where ferric phosphate will precipitate without the formation of alkaline earth phosphates, measurements were made to determine the pH of acidic solutions to which zinc oxide had been added. Tenth normal hydrochloric acid was treated with zinc oxide until, after heating and stirring, some solid remained undissolved. The solutions were then cooled and the pH measured electrometrically, using a quinhydrone electrode and a tenth normal calomel reference electrode. The zinc oxide used was Merck's Reagent Grade, both wet and dry process. The results fell between 5.4 and 6.0, values which should assure the quantitative precipitation of ferric phosphate.

Qualitative tests were then made in which solutions of ferric nitrate and the nitrates of the different alkaline earths were mixed with amounts of disodium phosphate somewhat less than the ferric ion, together with just sufficient nitric acid to dissolve the precipitate thus formed. A slight excess of zinc oxide was then added and the mixture heated for several minutes on a water bath. It was then centrifuged and the centrifugate tested for both iron and phosphate and for whichever alkaline earth had been used, after removal of zinc by ammonia and hydrogen sulfide. In all cases, tests for both iron and phosphate were negative and the test for the alkaline earth was positive.

A series of quantitative estimations was then made. Standard solutions were made up of disodium phosphate and the nitrates of ferric iron, cobalt, nickel, barium, strontium, calcium, and magnesium. In standardizing these solutions, cobalt and nickel were determined by elec-

[1] Treadwell and Hall, Analytical chemistry: New York, John Wiley and Sons, vol. I, 5th eng. ed., p. 474.

[2] Lundell and Hoffman, Outlines of methods of chemical analysis: John Wiley and Sons, New York, 1938, p. 90.

TABLE 1.

	Cobalt	Nickel	Barium	Strontium	Calcium	Magnesium
Grams						
Taken.....	0.189	0.176	0.180	0.196	0.196	0.129
Found.....	0.169	0.147	0.156	0.185	0.167	0.119

trometric precipitation, barium and strontium as sulfates, magnesium as the 8-hydroxyquinolate, and calcium as carbonate after precipitation as the oxalate.

Solutions of approximately 40 ml. containing about 0.09 g. of iron and slightly less sodium phosphate together with one of the other nitrates, were treated with just enough nitric acid to dissolve any precipitate formed. About 2 grams of zinc oxide was then added and the mixture heated to boiling and kept hot for five minutes. It was then filtered and the precipitate washed twice with small amounts of hot water. The filtrate was then made alkaline with ammonia and saturated with hydrogen sulfide to precipitate zinc together with cobalt or nickel if these were present. Colbalt and nickel were determined by electrometric precipitation after dissolving the sulfide precipitate in nitric acid, while the alkaline earth elements were determined in the filtrate, using the same methods as were used in standardizing the solutions. In all cases at least two samples containing the same metal were run. Since the investigation was being made to determine the suitability of zinc oxide for use in qualitative analysis, no attempt was made to recover the metallic ion that may have been carried down in the rather voluminous precipitate of ferric phosphate and ferric hydroxide. The results are summarized in table 1.

A rather considerable number of solutions containing either cobalt or nickel together with phosphate and at least one alkaline earth metal were analyzed for the metallic elements, removing the phosphate by means of zinc oxide. The methods for the detection of the cations were those given in *Elementary Qualitative Analysis* by Reedy, since that is the text used in our course in Qualitative Analysis. An exception was made in the detection of cobalt, where the formation of the blue cobalt tetracyanato-mercurate was used. This reaction has been studied by V. J. Cuvelier[3]. Although the compound itself is not of sufficient insolubility to be an extremely sensitive means of detecting cobalt, if the similar white zinc salt is precipitated, it carries down and is colored blue by extremely small amounts of cobalt. Since after the removal of phosphate by zinc oxide, zinc ion is present, it was felt that this would be the best means of detecting cobalt. However, since the presence of nickel makes the detection of cobalt less sensitive, as does dimethyl glyoxime, nickel should first be removed by dimethyl glyoxime, followed by evaporation

[3] V. J. Cuvelier: Z. Anal. Chem. 99, 15, 1934; 102, 16, 1935.

with nitric acid to destroy the excess of dimethyl glyoxime.

The following is the recommended procedure: On a small amount of the nitric acid filtrate remaining after the removal of manganese by potassium chlorate, make a test for iron by means of potassium ferrocyanide. If iron is not present, add to the remainder of the solution sufficient ferric chloride to cause a distinct yellow color. Then add sufficient ammonia to cause the formation of a slight permanent precipitate and then just enough nitric acid to redissolve this precipitate. Then add zinc oxide and heat for several minutes on the water bath, with stirring. The amount of zinc oxide should be sufficient so that some may be seen at the bottom of the container. If ferric hydroxide does not form, add more ferric chloride. Filter, or centrifuge, and after washing with hot water, discard the precipitate. Add sufficient ammonia to make the filtrate alkaline to litmus and if a precipitate forms, filter it out and discard it. Then saturate the solution with hydrogen sulfide, filtering or centrifuging out the precipitate which is examined for cobalt and nickel and reserve the solution for examination for the alkaline earths.

Dissolve the hydrogen sulfide precipitate in hydrochloric acid plus a little nitric acid, filtering out and discarding any sulfur. Test the resulting solution for nickel by making alkaline with ammonia and adding dimethyl glyoxime. When nickel is present, it should be completely removed in order to make the detection of cobalt more sensitive. For this purpose, the sodium salt of dimethyl glyoxime offers the advantage of being more soluble. Filter out and discard the red precipitate. To remove the excess of dimethyl glyoxime, acidify the solution with nitric acid and evaporate to dryness. Moisten the residue with nitric acid and again evaporate to dryness. Dissolve the residue in water after heating with a few drops of dilute hydrochloric acid, filtering out and discarding any residue. Then test the solution for cobalt by the addition of potassium tetrathiocyanato mercurate, made by mixing stoichiometric quantities of potassium thiocyanate and mercuric chloride. In the absence of cobalt, a white precipitate of the zinc salt should form. If cobalt is present, the precipitate will be blue, the depth of color varying with the proportion of cobalt.

The solution reserved for the alkaline earths is then examined for them by the usual methods, after removing ammonium salts with nitric acid.

In the development of the process, several senior students analyzed a considerable number of solutions for the ammonium sulfide group and the alkaline earths, without error. For the past two years, the method has been used in our regular course in qualitative analysis. The results have not been uniformly correct, but they do show a distinct improvement over those obtained previously with the basic acetate method, both in accuracy and saving of time.

SOME NEW DUCLAUX CONSTANTS*

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The Duclaux method for the recognition of volatile aliphatic acids[1, 2, 3, 4] is based upon the rate at which these acids distill from dilute aqueous solutions. The fraction of the total acidity of the original solution which comes over in each portion of distillate is characteristic of the acid being distilled and varies only slightly with the concentration of the solution and the presence of other volatile acids.

Duclaux used an original still charge of 110 ml. and collected ten 10 ml. fractions of distillate; the results were expressed as the cumulative percentages of the total acid distilled which were found in the successive fractions. He proposed that the values so obtained should serve for qualitative and quantitative analyses of a solution containing a single volatile acid or a mixture of two such acids.

The distillation method, as usually carried out, is empirical, and the values obtained vary with the size and form of the apparatus, with the method and rate of heating, and to some extent with the concentration of the original solution. Precision can be attained only by adherence to a standardized procedure. Data reported in the literature by different investigators show poor agreement because of differences in the procedures used[5]. Several authors have recommended that each analyst use his own equipment and conditions to redetermine the constants of the particular acids in which he is interested[6, 7].

TABLE 1.—DUCLAUX VALUES

Acid	I	II	III
Formic	3.6	4.0	4.5
Acetic	6.6	7.0	7.4
Propanoic	12.9	12.4	11.9
Butanoic	20.2	17.4	15.0
Methylpropanoic	29.0	21.5	16.3
Pentanoic	31.5	22.3	16.3
3–Methylbutanoic	35.9	23.9	16.2
dl–2–Methylbutanoic	36.6	24.0	16.2
Hexanoic	40.3	24.5	15.5
4–Methylpentanoic	42.4	25.2	15.4
2–Ethylbutanoic	46.5	25.5	14.0
Dimethylpropanoic	59.2	24.1	10.2

The technique used in the present work is based on an adaptation of Duclaux's method for qualitative

* Published by permission of the Chief, Illinois State Geological Survey.

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analysis, believed by the writers to have been reported first by Kamm[8], which can be found in most textbooks on qualitative organic analysis. In this procedure, 100 ml. of solution of known total acidity is placed in the distilling flask and three 10 ml. fractions of distillate collected and titrated. If a single volatile acid is present, the titration data may serve to identify it.

This paper presents constants for four acids not included in the tables given in the qualitative organic textbooks, namely: dimethylpropanoic acid, dl-2-methylbutanoic acid, 4-methylpentanoic acid, and 2-ethylbutanoic acid.[9]

Data are reported in the literature for distillations by different techniques of aqueous solutions of 4-methylpentanoic acid[10, 11, 12], and of 2-thylbutanoic acid[13, 14, 15]. No comparable data have been found in the literature for dimethylpropanoic acid or dl-2-methylbutanoic acid.

Experimental

The apparatus consisted of a 300 ml. round-bottom flask, an acute-angle connecting tube, a 30 cm. water-cooled condenser, and a curved adapter; all connections were 24/40 standard taper glass joints. The distance from the base of the neck of the flask to the top of the connecting tube was 14 cm.; the internal diameter of the connecting tube was 1.7 cm. The condenser was set at 30° from the horizontal. The flask was heated with a spherical heating mantle connected through a variable transformer.

The acids used were obtained from various manufacturers. All were of reagent grade except the hexanoic acid, which was procured as technical grade and redistilled under reduced pressure, a one-degree cut being collected. All acids gave satisfactory neutralization equivalents, but no further tests of purity were made.

For each determination 150 ml. of a 0.2 percent (by weight) solution of the acid was prepared, and duplicate 10 ml. aliquots were titrated to determine total acidity. A 100 ml. portion of the solution was placed in the distilling flask, a boiling chip added, and the flask heated so that 5 to 6 minutes sufficed for the collection of each 10 ml. fraction of distillate. Three 10 ml. fractions were collected in 10 ml. graduated cylinders, and each was titrated. All titrations were made with standardized 0.02 N sodium hydroxide, using phenolphthalein as the indicator. The standard alkali was protected from the air, and the water used for all solutions was distilled water that had been boiled to remove carbon dioxide.

Results are expressed as percent of the total acidity of the 100 ml. of solution used. The values given in the table are averages of from three to six determinations. The average deviations of the individual determinations from the average figures reported in the table ranged from a

[8] O. Kamm, Qualitative organic analysis, John Wiley and Sons, New York, 1923, pp. 57-8, 139-40.

[9] Except for the common formic and acetic acids, compounds described in this paper are named in accordance with the systematic "International Union Rules"; cf. A. M. Patterson: J. Am. Chem. Soc. 55, 3905-25, 1933.

[10] O. Jensen: Z. Untersuch. Nahr. u. Genussm. 10, 265-83, 1905.

[11] D. C. Dyer: J. Biol. Chem. 28, 445-73, 1917.

[12] J. Reilly and W. J. Hickinbottom: Sci. Proc. Roy. Dublin Soc. 15, 513-38, 1919.

[13] H. D. Richmond: Analyst 42, 125-32, 1917.

[14] H. D. Richmond: Analyst 44, 255-74, 1919.

[15] A. I. Virtanen and L. Pulkki: J. Am. Chem. Soc. 50, 3138-51, 1928.

low of 0.1 percent for the III value for formic acid to a high of 2.1 percent for the II value for 2-ethylbutanoic acid. In general, greater deviations were encountered in the work with the higher molecular weight acids.

The values for hexanoic acid and the first seven acids listed in the table deviate by as much as 25 percent from the values for the same acids determined on 2 percent solutions with different apparatus and reported in qualitative organic textbooks[8, 16, 17, 18], although they indicate essentially the same relative order of volatility.

It can be seen from the table that although the values obtained in some cases are sufficiently characteristic to identify the acids, differentiation in other cases—e.g., between 3-methylbutanoic and dl-2-methylbutanoic acids — by Duclaux constants alone should not be attempted. Even where differences are somewhat greater, as with pentanoic and 3-methylbutanoic acids, differentiation would not be reliable unless data of carefully run controls on the known acids under the same distillation conditions were obtained for comparison.

[16] R. L. Shriner and R. C. Fuson: A systematic identification of organic compounds: John Wiley and Sons, New York, 3rd Ed., 1948, pp. 146-147.
[17] S. M. McElvain, The characterization of organic compounds: Macmillan Co., New York, 1945, pp. 140-1.
[18] F. Wild, Characterisation of pure organic compounds, Cambridge, University Press, 1948, pp. 156-7.

GEOGRAPHY

THEORY OF INDUSTRIAL EXPANSION

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The localization of manufacturing industry, and especially the areal expansion of industry, has occupied my attention at recurring intervals for many years. In 1920, during the preparation of my *Source Book for the Economic Geography of North America*, I compiled a table which showed the remarkable concentration of industry in the states north of the Ohio and Potomac rivers and east from the Mississippi to the Atlantic. In that same year my interest in the distribution of manufacturing was quickened when, during the summer, the Swedish geographer, Baron Sten De Geer, was a visiting professor in our department at the University of Chicago. De Geer had just published his study of the manufacturing belt of Europe. He argued that "geography is the science of distribution," and that industrial distributions are among the major patterns in human affairs. Some time after returning to Sweden, De Geer published his famous monograph, *The American Manufacturing Belt*.

In 1924, the University granted me six months for a field study of the distribution of manufacturing. I was especially concerned with the prospects of expansion of industry westward across the Mississippi and southward into southern Illinois and other parts of the Ohio Valley. I began work in St. Louis where the late Lewis F. Thomas was making his pioneer study of the localization of business activities in metropolitan St. Louis. Then with the assistance of Clifford Zierer, now Senior Professor of Geography at the University of California in Los Angeles, I mapped and studied industry as far eastward as metropolitan New York. Subsequently, I made a map showing the outlines of the major manufacturing districts from Chicago and St. Louis at the west to the Eastern Seaboard. This map was first published in 1930 in the Colby-Foster *Economic Geography for Secondary Schools*.

In 1931, I was asked by a group in Dallas to study the possibilities of industrial development in eastern Texas, especially in Dallas. Mrs. Colby helped with this study. We foresaw much industrial growth for eastern Texas but our work was none too popular because we predicted more industrial growth for Houston than for Dallas.

This year, in studying southern Illinois, I have returned to the question of possible greater industrial growth in the southern part of the state. I found that Oliver Beimfohr already had underway a study of the industrial potential of southern Illinois. We joined forces in compilation and in the field and have completed an industrial survey of the 32 southern counties of the state.

As I worked this year, I came to the realization that progress in the analysis of industrial expansion was handicapped by an absence of basic theory. That conviction led to the preparation of this paper.

Argument

Three conflicting ideas in regard to industrial expansion are current today. The first is shared by some labor unions and chambers of commerce. Their idea is that industrial expansion will provide employment for more people, or introduce new forms of employment into their areas. Their objective is larger payrolls. The second idea of industrial expansion is held by government. It is motivated by the desire to spread the risk of destruction from atomic bombs, and thereby make more certain that in time of war, supplies of materials will be forthcoming. The third idea is that of industrial management. In this case the goal is a high level of production which will yield a satisfactory profit on the investment.

Each of the foregoing ideas of industrial expansion might lead, (1) to an increase of manufacturing enterprise in an area where industry already is established, (2) to the decline of industry in a given industrial area, or (3) to the appearance of industry in areas where previously it had not been in evidence. Any of these types of expansion would affect the productive plant and the economy of an area, and thus would affect its economic geography.

Although the actions of labor, government, and management are likely to be interrelated in coming months and years, organized labor is becoming a new monopoly of as grave national concern as were the trusts and the railroads in their day. Government, in its enthusiasm for military and international power, appears likely to ignore the premise that it should be for the people and by the people. Industrial management in its search for profits at times seems to forget that legitimate profits must come from high levels of production effectively transferred to a higher standard of living for people in general.

Unless the current conflicting ideas of industrial expansion can be reconciled into a rational line of action, the national economy is likely to be seriously handicapped. Manufacturing now provides about 25 percent of our peacetime jobs, and output of industrial employees underlies many other kinds of economic activity. Everyone has a stake in the conflict.

Are the conflicts of interest in industrial expansion open to solution under the semi-chaos which prevails at present in the national and international scenes? One way to approach such a question is to search for the theory and the principles which underlie industrial expansion. On account of the number and variety of considerations which theoretically may be involved in the location and expansion of industry, we must search for the prime considerations, that is, for the explanation of expansion based on thought, observation, and reasoning. As any expansion of industry will involve intensification or dispersion of manufacturing forms, functions, and patterns, a rational theory of expansion must meet the tenets of the science of

distribution, that is of geography.

Of the three ideas of industrial expansion, the one emphasizing profit appears to be most rational in terms of the science of distribution. This is due to the fact that in order to get high levels of production, the basic factor in profits, the expansion must permit industry to make efficient use of natural resources, human resources, and market demand. The objective is to place expansion in a line of flow from resources to consumption, or in other terms, to take full advantage of the regional and interregional patterns of demand and supply. In this connection, it is evident that any theory of industrial expansion must be in harmony with the essentials of pattern—geography—and also with the essentials of price or cost—economics.

Any useful theory of industrial expansion must take account of incentives which lead men to assume the risks inevitably associated with industrial enterprises. These incentives may be classified into six types.

Type one depends on the use of local raw materials as, for example, the lumber industry of northern Michigan and Wisconsin depended upon the large stands of native white pine.

Type two derives from the site of invention. The Ford Motor Company in metropolitan Detroit is an example. Mr. Ford invented his automobile in a suburb of Detroit, and Detroit has always been the home of the parent company.

Type three derives from expansion of an industry from an area in which a parent organization has been established for a long time into a new area. United States Steel at Gary, Indiana, is an illustration. This company originated in metropolitan Pittsburgh but having outgrown its facilities there, it established a new and greater plant at the head of Lake Michigan. As it was a going concern long before it made its appearance in Indiana, and as Gary possessed well-known regional advantages, the new plant in the new area has been highly successful.

Type four is the development of industry in an area in response to a big or a new market demand. The manufacturing of lumberman's supplies in Portland, Oregon, and Seattle illustrates the idea. Lumbering operations in the Pacific Northwest are so different from what they were in the lake states that the kind of saws, the kind of tools, and the kind of clothing well-suited to operations in the lake states did not suit the conditions in the Northwest. As a result, new industries sprang up to meet the new demand.

Type five comes from the initiative of previously established wholesale houses, or other marketing agencies. The boot and shoe industry in St. Louis is an example. In the early days, St. Louis wholesalers bought their shoes from Massachusetts, New Jersey, and other eastern states. Subsequently, they manufactured shoes on their own premises by bringing the parts of shoes in carload lots and at low rates to St. Louis where they were assembled into finished products and sold through already established channels.

Type six represents individual or group initiative in imitating or following the example of successful in-

dustries already established. In North Carolina, for example, the cotton mills originally were of three sorts. Some were branches of New England factories and some were started by wholesale firms operating out of Baltimore. Others were started by local people who argued that they could make a success of cotton manufacturing on their own. In some cases, a company was organized by local people and stock sold as low as $.25 a share in order that everyone in the community could be part owner of the enterprise. Some of these firms turned out to be eminently successful and were and still are owned and operated by local people.

The history of manufacturing in the United States furnishes abundant evidence that successful industry can develop in any of these ways or in any combination of them. It should be understood, however, that acquaintance with the technology of an industry is necessary before a man is stimulated to improve a part of that technology. All the famous men in the early days of the automobile industry had training in some phase of the transportation business. Buick and Studebaker, for example, were carriage and wagon manufacturers before they went into the automobile manufacturing. Chrysler came out of railway transportation and Ford had worked in a plant which made engines that powered the early naphtha launches.

Much light has been thrown on the problems of industrial expansion by McLaughlin and Robock in their remarkably fine study, *Why Industry Moves South*.[1] They point out that businessmen choose locations for industrial plants in order to obtain low costs or a high sales volume, or both. They also argue that "anyone hoping to understand or influence the geographic distribution of manufacturing plants must become familiar with the specific objectives underlying this type of business decision." In analyzing the large amount of case material made available to them in their study of the recent expansion of industry in the South, McLaughlin and Robock found that most plant locations were oriented in terms of materials, labor, or markets.

In considering the importance of location in terms of materials, these authors point out that where materials are perishable or not freely transportable, where costs of materials are an important part of total delivered costs, or where the materials are more expensive to carry than the finished product, an industry should be located close to the point of material production. This is especially true if it is important to increase the supply of materials.

Orientation of industrial expansion in terms of labor is wise if the cost of labor is a big part of the total cost, and if the cost of transportation is an insignificant part. If a process calls for much labor, the expansion should be into an area of lower-cost labor. In this connection I wish to point out that this does not imply that labor may not be well paid in an area where labor costs are

[1] Glenn E. McLaughlin and Stefan Robock, Why industry moves south: National Planning Association, Committee of the South, Report 3, 1949.

lower than elsewhere. It does imply, however, that the regional advantages of housing, food, clothing, and heating, namely the geographic basis for lower labor costs, are passed on, in part at least, to the manufacturer. If labor or any other group tries to divert all of this advantage to itself, it destroys the regional advantage for manufacturing enterprises.

Expansion in terms of markets according to McLaughlin and Robock should take place:

a. Where finished products are perishable or not freely transportable.
b. Where transport costs are an important part of total delivered costs and the finished product is more expensive to carry than the materials required.
c. Where service, convenience to the customer, or regional loyalty is involved in achieving the desired level of sales.

A theory of industrial expansion must provide for an adjustment to pattern and cost in terms of three types of orientation, namely, orientation in relation to material resources (including power), to labor resources, and to market demands. Evidence in support of the theory comes from many directions. For example, of the new plant locations in the South studied by McLaughlin and Robock, 30 percent were located in relation to materials, 25 percent in relation to labor, and 45 percent in relation to markets.

Expansion in terms of materials is illustrated by the localization of about 85 percent of the petro-chemical industry in eastern Texas to take advantage of the huge regional reserves of petroleum and natural gas. An example of expansion oriented to labor supply is the recent establishment of a factory making women's cotton dresses at Herrin in southern Illinois. Because of a surplus of labor in the area, the company found no difficulty in hiring the 600 women workers essential in its operation. Industry oriented to markets is well illustrated by the recent rapid expansion of manufacturing in metropolitan Los Angeles to take advantage of the ever-growing markets on the West Coast.

Some industrial localization is strongly oriented to one of the three conditions just described. Actually, however, every successful expansion probably is oriented to a combination of the three. This truth emphasizes the attractive quality of regions which possess raw materials, labor, and markets in reasonable juxtaposition. By reasonable juxtaposition I mean effective alignment in terms of distance and space, and harmonious arrangement in terms of cost. Obviously an area that possesses the whole battery of advantages is more certain to witness industrial expansion than areas that possess only a single type of advantage. Such a regional equipment of materials, labor, and markets explains the continuous growth of industry in the major manufacturing belt extending from Chicago and St. Louis at the west to Boston, New York, and Baltimore at the east. It is not surprising that this belt got about 80 percent of the government contracts for manufactured products during World War II.

The preceding argument does not encourage the expectation of a great dispersion of manufacturing, even under the threat of the atom bomb and the Federal Government's present encouragement of dispersal.

The concentration of manufacturing in the great transportation and commercial centers like New York, Chicago, and Los Angeles is logical because they possess marked advantages in the assemblage of raw materials, the availability of labor, and in accessibility to markets. For this reason, it is to be hoped that the threat of atomic attack and the interest of the government in functional dispersal will not cause industry to expand along illogical and costly lines.

Formulation

The preceding analysis has shown that our theory of industrial expansion should be in harmony with the major types of industrial expansion, namely (1) further growth of an industry in an area long occupied by industry, (2) outward or peripheral expansion about the borders of an industrial belt, (3) migration of industry from a parent area into an area previously without industry, and (4) the birth of industrial development in a new area under regional creative effort.

The major premise of our theory is that the entire industrial structure evolves from creative ideas implemented by inventions, processes, and methods into an advance in productive technology. This means that the mind of man is an all-important essential.

The second premise is that the beginnings of productive technology are highly regional and develop out of long experience with simpler forms of the same type of productive effort. An example was the invention of the spinning-jenny and the power looms in the Manchester section of England where textile manufacture had slowly flowered in the hands of the guilds.

The third premise is that productive technology should be oriented in orderly fashion to materials, power, labor, and markets. Localization of a particular establishment in relation to one of these essentials may be wise, but such orientation will not produce the large well-balanced display of industry which raises it to a major rank in the economy of a region.

The fourth premise is that orientation of industries to materials, power, labor, and markets seldom or ever is attained in a single region, but instead is secured by interregional alignments in which low-cost continuous transportation is a prime factor.

The final premise is that only a relatively few areas in the world are so well placed and so well equipped with the essential natural and intellectual resources, that large-scale and diversified industry can become a major segment of their economy.

In conclusion may I point out that if our theory is sound, it might be utilized in judging the merits of plans for the expenditure of money and effort on the part of our Federal Government in foreign areas.

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ONE SQUARE MILE OF ICE: AN EXPERIMENT IN GEOGRAPHICAL ANALYSIS

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There are many definitions of geography, most of which state or imply the concern of the subject with man. Even if there are no inhabitants in a particular area, it should be possible to evaluate that area in terms of man's needs and prospects. As a test of this idea, suggested by J. H. Garland and F. W. Foster, this analysis of a small portion of an arctic icecap is attempted.

Nordauslandet (Northeast Land), the second largest island of the Spitsbergen archipelago, is largely covered by several separate domes of ice. The southwesternmost ice dome, Vegafonna, has a roughly circular plan and a maximum surface elevation of 1400 feet. Its mile-square summit has a flat surface, broken only by small sastrugi and, in summer, by tiny melt-water runnels which discharge onto raised beaches and muddy lowlands a few miles distant.

The local climate is Köppen's EF or Icecap type, but of a very mild variety. Precipitation, falling mainly in summer, is adequate to maintain the ice in its present static condition, despite the fact that temperatures do not often fall below 0°F. except in midwinter, when the sun is below the horizon and the moderating sea is masked by ice. In summer, air temperatures are frequently above 32°F. and contact fog and wet-snow surfaces are common phenomena.

Soils and vegetation are totally lacking, as are rock outcrops. There is no reason to believe that there are any mineral resources in the bedrock below the ice.

By contrast, animal life is relatively abundant. Enormous pawmarks in the snow testify to the passage of polar bears in search of new seal-hunting grounds, and smaller tracks suggest that a scavenging fox is trailing the bears. Overhead in summer fly fulmars, terns and other migrant birds, whose eggs are also sought by foxes.

This landscape of ice and snow, totally unmodified by man, presents certain possibilities to people from civilized lands. The flat surface offers good travel for the sledges of explorers and soldiers,and a satisfactory landing ground for ski-equipped planes. Summer fog and wet snow may ereate difficulties for both forms of transport, but the plentiful supply of water (in liquid and solid state) is as always a great convenience. The lack of agricultural possibilities means that most food must be imported, but a few hours' hunting will often ensure an adequate supply of seal, duck, and other types of meat, besides a few eggs, at the right season.

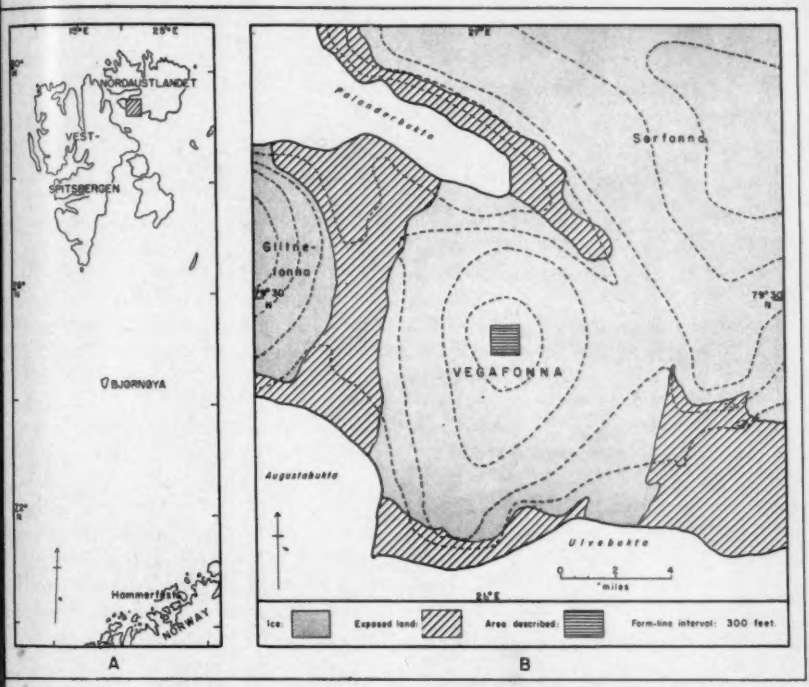

FIG. 1.—A. General location. The shaded area is that included in B. B. The square mile of ice in its local setting. The Norwegian endings "bukta" and "fonna" mean "bay" and "ice dome," respectively. (Amended from A. R. Glen, The latest map of North East Land: Geog. Jour. 98: 206-207, 1941.)

Man can (and occasionally does) exploit the natural environment in another way. Observing the routes normally followed by bears and foxes, he lays out traps and in one winter collects enough skins to bring him a handsome reward for his privations.

From this experimental study, we conclude that even an ice desert may have definite significance for man and may be analyzed by the normal techniques of the geographer.

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A RELATIVE RELIEF MAP OF ILLINOIS

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A map of relative relief purports to depict quantitative differences in terrain conditions between areas. The map is constructed from an analysis of topographic maps, but the method of construction permits considerable latitude.[1]

First a rectangular grid is superimposed on the area to be mapped. The size of the mesh of this grid may vary considerably. The upper limit would be established by whatever the cartographer believed to be the largest area to which the term local relief could be applied. The smallest size grid would be one on which the individual rectangles were so small that for many of the rectangles the topographic map itself would furnish no reliable information about elevation differences within the rectangle. After the grid size has been decided and the grid superimposed the maximum difference in elevation within each rectangle is determined by inspection of the topographic sheets.

When the grid has been filled with the maximum relief values, a second arbitrary decision is involved. The number and size of the relief interval classes must be determined, and this involves subjective decisions. After this is done either an isopleth map or a dasymmetric map can be drawn indicating the local relief of the entire area. This involves, however, a third set of arbitrary decisions; that is, the extent to which the areas will be generalized. How many contiguous isolated rectangles will be established as the lowest number which will be depicted as a separate region? What will be done with a small scattered group of rectangles surrounded by rectangles with a different class interval? All such decisions are arbitrary. Finally, there is the problem of the interpretation of value data in the drawing of boundary lines. Anyone who doubts that great variations are possible in this stage of the process is referred to the article by Mackay.[2]

The point emphasized here is that the objectivity of a relative relief map is much more apparent than real. If the author of a map of relative relief tells the reader in sufficient detail exactly how the map was made it would be possible (excluding the factor of error) to reproduce the map exactly from the same data using precisely the same methods. Presumably this is true of any map. In practice, however, this has never been done; and moreover, would probably not be worth doing. Put succinctly, a high degree of subjectivity is involved in making a map of relative relief. The map-

[1] G. H. Smith, The relative relief of Ohio: Geog. Rev. vol. 25, 1935, pp. 272-284. Also W. Calef, Trans. Ill. Acad. Sci., vol. 43, 1950, pp. 110-115.

[2] J. Ross Mackay, Some problems and techniques in isopleth mapping: Econ. Geog. vol. 27, 1951, pp. 1-9.

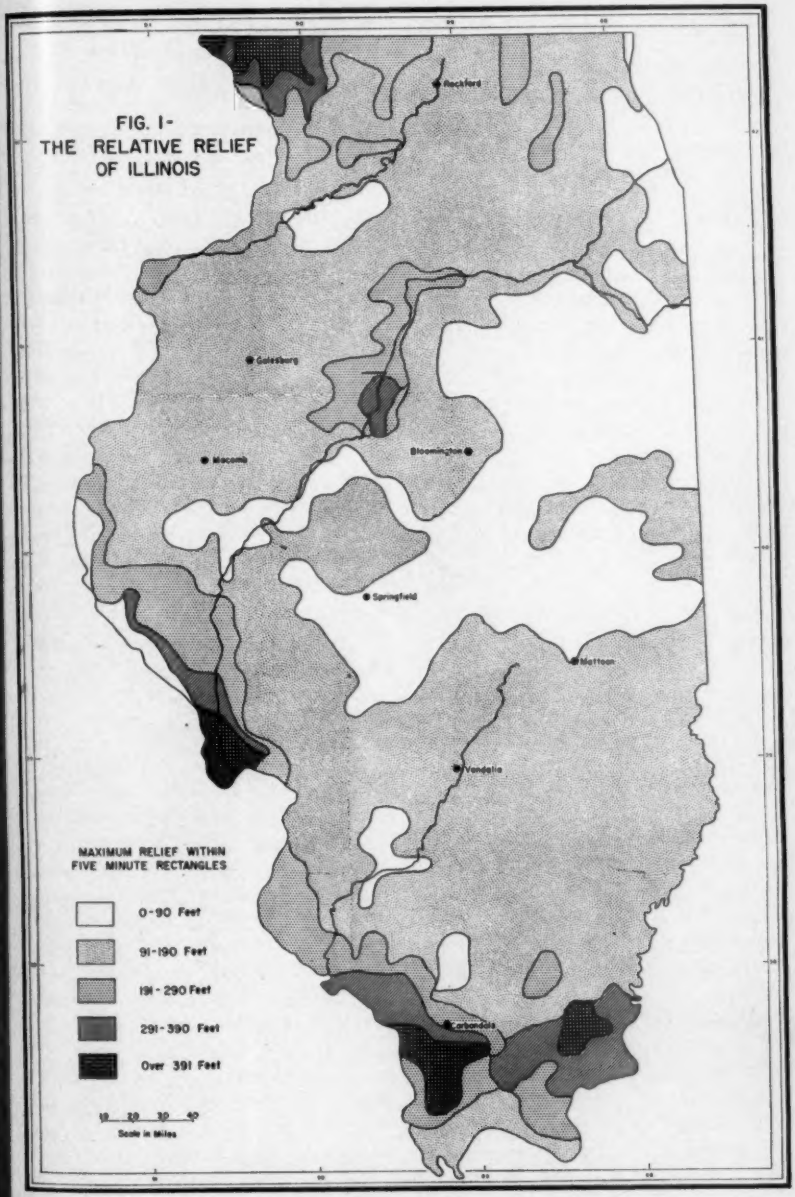
FIG. 1-
THE RELATIVE RELIEF
OF ILLINOIS
Rockford
Galesburg
Macomb
Bloomington
Springfield
Mattoon
Vandalia
Carbondale
MAXIMUM RELIEF WITHIN
FIVE MINUTE RECTANGLES
0-90 Feet
91-190 Feet
191-290 Feet
291-390 Feet
Over 391 Feet
Scale in Miles

maker adapts the method to show what he thinks should be shown, and he modifies the method for the same purpose, almost as much as he draws his lines in conformance with the figures which his version of the method dictates. The somewhat odd appearing map of Illinois shown in figure 1 probably would be "improved" by greater generalization of the raw data. The author, however, was so acutely aware of the degree of subjectivity and generalization that had gone into the creation of this version that he refrained from any further attempt to "improve" the map by additional smoothing of lines or adjustment of areas. Keeping these characteristics of a relative relief map in mind we may survey briefly the major terrain characteristics of Illinois as revealed by the map.

The popular concept of Illinois as a vast flat plain is relatively accurate. Only along the western and southern borders of the state does the state have extensive areas of strongly rolling or hilly land. The greatest local relief is in the Ozark outlier in southern Illinois where local relief in excess of 600 feet is not uncommon. In northwestern Illinois, in sections of the Driftless Area, there are a few places where the local relief exceeds 500 feet.

In a very rough way we might visualize the arrangement of terrain features in Illinois as consisting of three interrupted concentric bands: the Grand Prairie Area is largely an area with less than 90 feet of local relief; it is surrounded by a wide band of land with maximum local relief between 90 and 190 feet; that, in turn, is bounded by lands of still greater relief.

Glacial moraines in Illinois are not sufficiently prominent to stand out clearly from the surrounding areas, except where they have been dissected by erosion, as in the vicinity of Peoria.

Relief in Illinois is closely related to the degree of erosional dissection and the areas of higher relief everywhere lie closely adjacent to the three major streams of the region —the Mississippi, Illinois, and Ohio.

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A SURVEY OF ILLINOIS WATER SUPPLY PROBLEMS WITH SPECIAL REFERENCE TO CHARLESTON

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It is often difficult for people to realize that Illinois with its many well-developed river systems and ample average precipitation faces water supply problems. Upon consideration of the domestic and industrial state-wide water use, which totals over 370 gallons daily per capita, the necessity for maintaining and increasing available sources becomes evident.

Subsurface Water Supply Problem

The principal subsurface water problem in Illinois is the reduction of quantity from the lowering of water levels. Subsurface water can be procured in various quantities from eighty percent of the areal extent of Illinois (fig. 1).

Contrary to common opinion, the state's subsurface water resources are basically in good condition. That is, approximately 95 percent of the subsurface water area of Illinois is not faced with decreasing water levels. However, at certain locations where large urban concentrations have relied on subsurface water, there are serious water supply problems. Furthermore, fifty percent of the state population lives in these urban areas where water levels are being seriously lowered by concentrated pumpage. It can be easily understood, then, why there is a common suspicion that subsurface water resources throughout Illinois are dwindling.

The problem areas are Chicago and its suburbs and Joliet, Rock Island, and Peoria, especially Chicago and Joliet, where water levels in the bedrock deep wells have dropped as much as 400 feet over a period of sixty years. Figure 2 shows the recession in the Joliet city wells from 1890 through 1950. Some Chicago suburbs, one-time users of subsurface water, are forced to obtain water supplies from Lake Michigan.

As far as can be determined, the East St. Louis area and Peoria area rank first and second, respectively, in the world's per capita use of subsurface water per day. Because the Illinois River's highly silted floor allows little river water to infiltrate and recharge the aquifers beneath Peoria, the Illinois Water Survey has constructed an experimental infiltration pit near the river. During cooler months of the year the pit replenishes underground aquifers directly in quantities up to two million gallons daily, which is ten percent of the daily recharge needed for Peoria.

Subsurface water resources are being seriously depleted in only five percent of Illinois' subsurface water area. However, this small area's supply difficulty is becoming an acute problem for municipal and industrial planners.

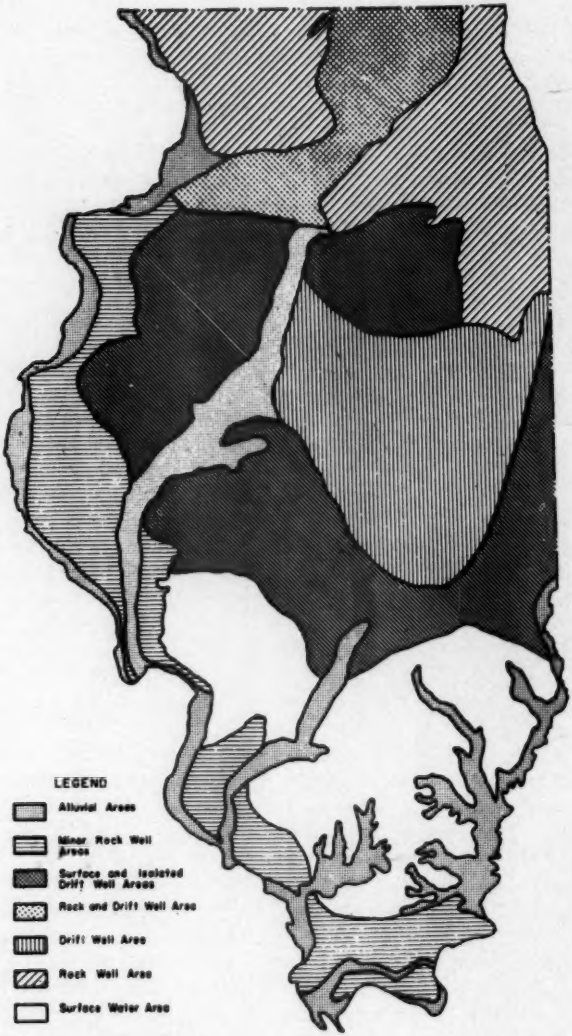

FIG. 1.—Water sources of Illinois. Subsurface water is found in all areas except the unmarked southern region.

Surface Water Supply Problems

The quantitative decrease of surface supplies in Illinois has been influenced by pollution, but pollution is subordinated to a more important problem. For example, it has been calculated that waste disposal in the Illinois River totals one part per million as compared to 418 parts per million of silt in the river.

Reservoir silting and silt pollution have become the major problems of surface water sources. Unfortunately these problems have become fully recognized only in the past twenty-five years. Twenty-five percent of fourteen sedimentation surveys in the past sixteen years have revealed such damage to the lakes as to necessitate immediate consideration of additional facilities. Of the 600 public supply systems in Illinois, approximately 100 depend on surface water sources other than Lake Michigan. However, concerning quantity used, municipal surface water pumpage is nine times greater than subsurface water pumpage.

Figure 3 compares industrial use of groundwater and surface water in nine major industrial areas. Over 350 industries in Illinois use subsurface water totaling 258 million gallons daily, but the surface water pumpage by 200 industries is six times larger, totaling 1.753 billion gallons daily. There can be no doubt of the necessity and value of maintaining surface water sources in Illinois.

In all reservoirs, which have been constructed to trap and contain the irregular seasonal runoff, the particles of silt settle throughout the lake bottom. Usually the silt also forms deltas or natural levees at the location of stream entrance to the reservoir.

The volume of silt deposited in reservoirs depends upon seven characteristics of the watershed area. These are watershed size, soil permeability, amount of rainfall, degree of

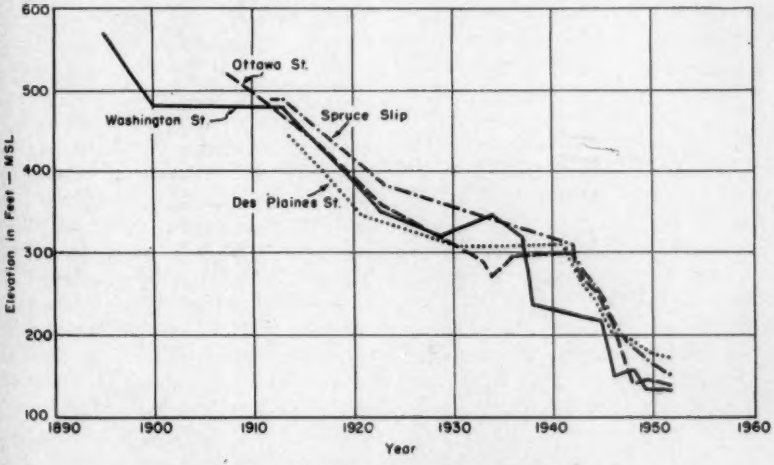

Fig. 2.—Recession in Joliet city wells.

land slope, reservoir capacity, stream gradient, and land use.

Silting and soil pollution as problems of surface water sources are only end results of the real problem, and that is soil erosion. The areal extent of the various degrees of slope and the resulting degree of erosion are factors of the watershed that directly affect silting. Another characteristic is the amount of runoff as determined by the rainfall over the watershed and the permeability of the watershed's soils. A small reservoir receives a larger volume of silt per square mile of watershed than does a larger reservoir. In a very large watershed, it is obvious that the distance to be traveled by the sediment will be greater; and therefore the sediment has many more opportunities to be deposited before it reaches the reservoir.

From experiment and detailed sedimentation surveys, a ratio has been devised that is indicative of future reservoir sedimentation. This ratio is reservoir storage capacity in acre-feet divided by the number of square miles in the watershed area. From examination of the seven causes of sedimentation, it appears that present trends in land use within the watersheds are causing the recent increase of reservoir silting in Illinois.

Several remedial measures are available to solve severe silting and obtain an adequate supply. Selection of such measures is dependent on the problem area's physical and economic situation. Reservoir dredging, dam raising, additional reservoir construction, and controlled land-use conservation throughout the watershed are the primary solutions. When reservoir construction ends, reservoir destruction begins.

Development of New Sources

Illinois has available approximately 600 useful reservoir sites. Furthermore, with careful planning and control, the state's surface water sources can support a population ten times the present population. Further growth of many industrial areas using subsurface water is deterred by insufficient volume. The state's subsurface water distress areas reflect a trend towards dependence on surface water sources, as is the case in many suburban Chicago cities.

The inadequacy of groundwater for municipal supplies was a major factor behind the fifteen percent increase in the number of city surface reservoirs during a seven year period ending in 1944. The increasing attempts to find new water sources also include probing the major buried bedrock valleys. As example, in order to obtain necessary water for the recent industrial development at Tuscola, according to newspaper reports, the possibility of drilling wells in the buried Mahomet-Teays Valley, twenty-two miles from Tuscola, is being considered. The expense and problems encountered in pumping and moving this water indicate the amount of trouble industry is willing to undergo in its quest for a satisfactory water supply. Champaign, to maintain an adequate municipal supply, has had to sink new wells in the same buried valley. Rockford, a city long dependent on bedrock sandstone aquifers is beginning to augment its supply with subsurface water obtained from a preglacial valley. Illinois may be approaching

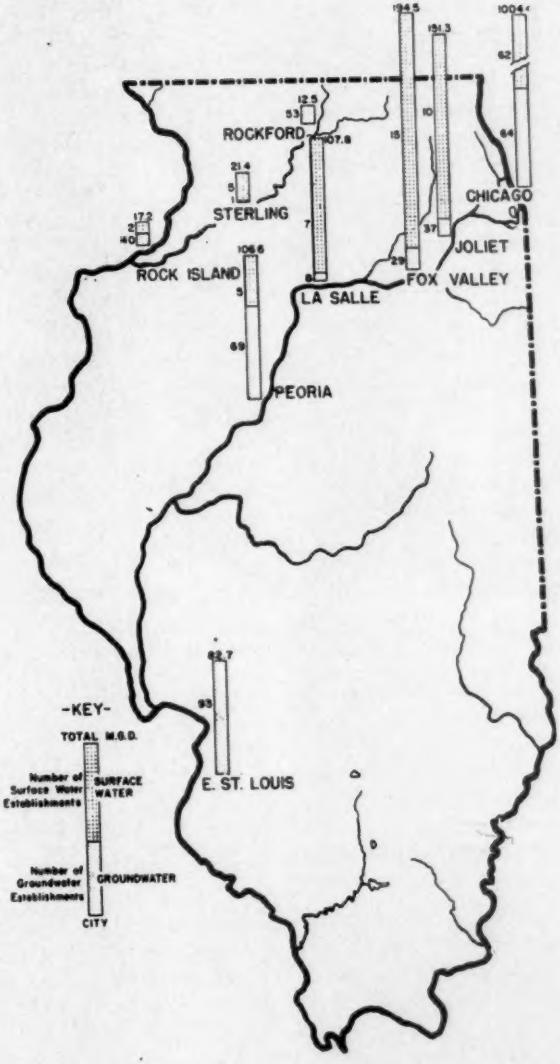

FIG. 3.—Total water use of nine industrial areas of Illinois representing total pumpage, groundwater and surface water proportional use, and the number of industries for each source.

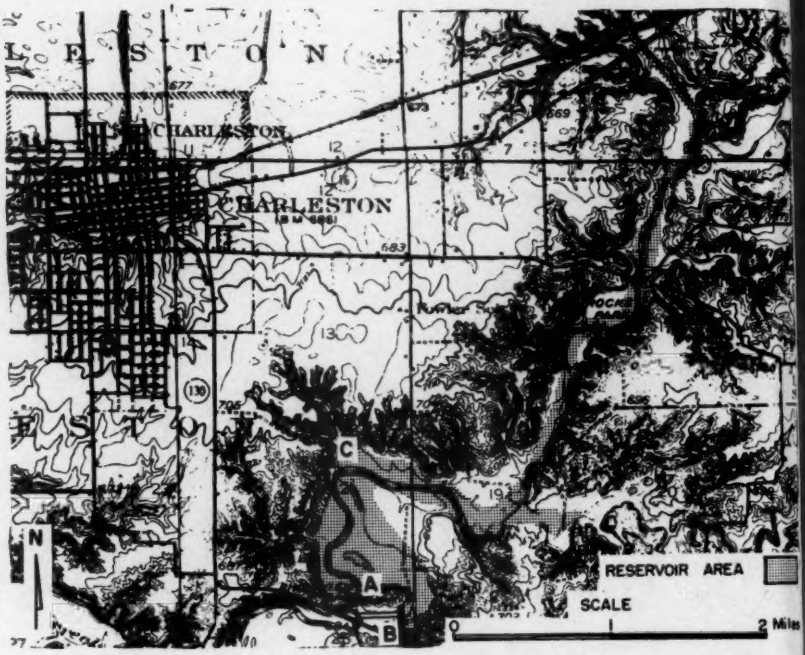

FIG. 4.—Topographic map of Charleston and vicinity showing the arrangement of water supply facilities. New Lake Charleston is approximated by dots.

a period in the water supply situation in which availability of large quantities of subsurface water in buried valleys will be a deciding factor in industrial location.

WATER SUPPLY SITUATION AT CHARLESTON

Charleston's water supply situation is typical of past, present, and future problems faced by the majority of surface water supplied cities in Illinois. For 76 years the city has obtained its water from the south-flowing Embarrass River two miles east of the city (fig. 4). The drift and bedrock underlying Charleston and its vicinity have no large water-bearing formations. In the area the drift ranges from 40 to 75 feet of sands and gravels. The few shallow drift wells in the area furnish limited quantities of two to ten gallons per minute, and suffer a rapid "drawdown" after continual pumping. The few wells drilled into bedrock have brought in very small quantities of highly mineralized, corrosive water. With such an unfortunate subsurface water situation, an adequate surface supply has been a necessity for Charleston.

The water has always been obtained at an intake about one mile southeast of the city (point C, fig. 4) where the waterworks are located. Water flowing past the point of in-

take represents runoff from a drainage area of approximately 800 square miles. The river is incised to a depth of over 100 feet, forming compact clay till, which contains few scattered lenses of water-bearing meanders and steep-sided valley walls.

From 1876 to 1895 the city supply depended entirely on river flow with no damming or reservoir supply. In times of low flow, the river bed was plowed to allow free inflow of the spring water that fed the river. To get a more regular supply in times of low flow, an eight-foot high channel dam was constructed in 1895 on the Embarrass a mile below the intake (point A, fig. 4). Until 1912 all city water was untreated. One former city father said, "We hadn't worried about pollution, as all towns dumping sewage into the river are at least fifteen miles upstream." During 1912 and 1913 a filter plant and settling basin were built, and by 1918 a small elevated tank had been constructed and meter installation begun. In 1925 one of fate's blessings in disguise occurred when the waterworks plant burned. After this disaster modern electric pumps with complete new facilities were installed, which made Charleston's supply facilities temporarily satisfactory.

By 1927, the city consumed 250,000 gallons daily above the capacity of the filters, so that 20 percent of the water used was raw river water. From 1930 through 1939 minor improvements were made at the overtaxed waterworks, but by 1940 the inadequacies of source and facilities were becoming so serious, that the city began long range planning for a new reservoir and complete waterworks improvement. During the following three years several plans were considered for a new reservoir, which mainly concerned use of the various Embarrass tributaries near Charleston. However, in late 1943 a plan for improvement was decided on calling for the construction of two dams (locations A and B, on fig. 4). The bonds were issued, land purchased, and the present reservoir was realized in 1947. The new reservoir impounded 860 million gallons over an area of 400 acres.

Since reservoir completion and general waterworks improvement, other problems have arisen. Several temporary water shutoffs have resulted from breakage of the single water main that connects the waterworks at the reservoir and the city. The major problem at present is the need for an extra connecting main and a large new elevated water tank within the city. Both items were called for in the long range improvement plan, but have not been constructed. For this reason fire insurance companies were forced to raise rates in Charleston last year. However, the people of Charleston have just this February voted to issue the necessary bonds to complete the needed water supply improvements. Therefore, 1952 should complete a very fine water supply system for this city.

Except for periodic repairs and replacement of the waterworks equipment, the future holds possibly one major problem for Charleston to consider, that of loss of reservoir volume through silting. Admittedly, silting is not an immediate problem, but its possible future seriousness will require periodic investiga-

tions. Since no accurate sedimentation survey has been made as yet, any prediction of the rate of silting and the date of serious loss of volume is highly empirical. However, to get an estimation I have selected Lake Decatur for comparison, as it has many silting characteristics similar to Lake Charleston.

From this comparison, it appears the watersheds are not markedly different in respect to rainfall and soil types; therefore the proportion of runoff is approximately the same for both. Lake Decatur's watershed totals 906 square miles as compared to Charleston's 800 square mile basin. Degree of slope within the watersheds is also similar with low slopes totaling 93 percent of the Decatur area and 89 percent of the Charleston watershed area. A factor which indicates possible greater Lake Charleston silting, is that a much larger percentage of the Decatur watershed is under the control of drainage districts. Stream gradients are almost identical for both rivers, and the land use in both watersheds indicates onlya three percent difference in the amount of land in intertilled crops. Therefore, except for the factor of impounding volume, the lakes are quite similar, and may possibly have approximately equal silting rates. A big factor in silting is the ratio of reservoir capacity to watershed area, which figures out to be 22 acre-feet per square mile for Lake Decatur and 3.25 for Lake Charleston. Sedimentation experts consider any lake with a ratio below 100 to be in danger of serious volume loss from silting, and the lower this ratio the more dangerous are the silting possibilities. Actual studies of silt in Lake Decatur indicate a 1.1 percent loss in reservoir capacity yearly for the past thirty years. Further empirical application in relation to the 3.25 ratio and the trap efficiency of Lake Charleston, indicates that Lake Charleston would be losing 1.75 percent of its original capacity per year. If this be true, the lake has lost approximately nine percent of its capacity since construction ended.

Summary

The frequent water supply problems in Charleston's past are but a reflection of the common lack of planning in respect to the requirements of the ever-present population and industrial growth. Fortunately the city here now appears to have the water supply situation under control. It must not relax its present ambitious policy in the future. The typical trial-and-error water supply development with its resulting inadequacies has been and is being repeated in many cities and towns throughout Illinois.

With the increasing statewide, dependence, development, and use of surface water supplies, the difficulties, as encountered at Charleston, and the general water supply problems should be, can be, and must be avoided to maintain adequate supplies in Illinois.

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A METHOD OF CONSTRUCTING AVERAGE SLOPE MAPS

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The construction of an average slope map involves a major problem. If a strictly statistical method is used, terrain variations clearly visible on topographic sheets or in the field may be either suppressed or the boundaries may be distorted. If, however, terrain regions are outlined by inspection of the maps and the average slope of the regions ascertained, the problems of degree of generalization and of the treatment of transition zones immediately arise.

Construction of the sample map of northwestern Illinois (fig. 1) from topographic sheets of the U. S. Geological Survey involved the following steps.

(1) An arbitrary decision was made concerning the number of slope classifications to be used and the slope percentage indices at which breaks would occur. Because general slopes in the selected area were known to be moderate, only four such classifications were deemed necessary. The slope classes used were: Less than 1 percent, 1-5 percent, 5-9 percent, and over 9 percent.

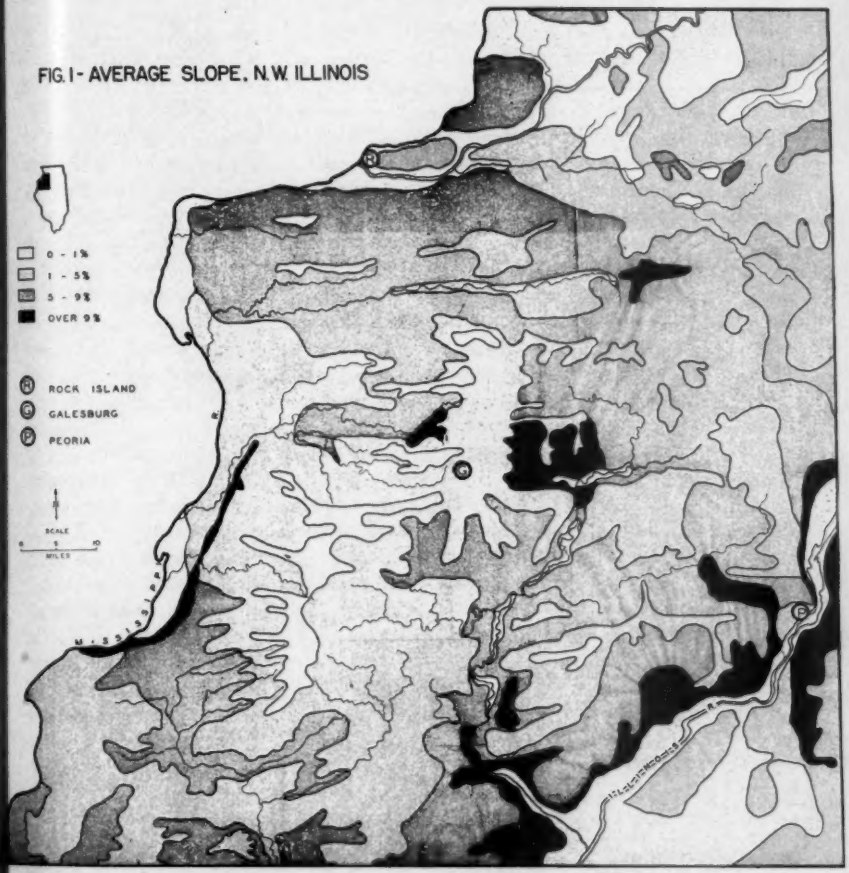
(2) The critical percentage indices were then translated into terms utilized by Wentworth in his quantitative method of determining average slope.[1] Thus it was found that on a standard topographic sheet with a contour interval of 20 feet, any area wherein there were 1.7 or fewer contour intersections per average mile along a random line had an average slope of less than 1 percent. Areas characterized by averages of 1.7-8.4, 8.4-15.2, and over 15-2 intersections were placed respectively in the 1-5 percent, 5-9 percent, and over 9 percent classifications. This eliminated the necessity of using the average slope equation for ascertaining average slope in each area.

(3) Boundaries were then drawn between areas which, from inspection of topographic sheets, were believed to have significantly different terrain characteristics. This method has been used previously by Raisz and Henry.[2]

The resulting map portrays slope conditions in the general manner in which they are found in reality. The most pronounced and continuous appearance of highest slopes is in the Peoria section where the Illinois River traverses the Bloomington moraine. Minor expressions of such slopes are found in Illinoian drift along the Mississippi and Spoon rivers. Transitional areas of moderate slope tend to be in juxtaposition to steepest slopes and also to coincide with drainage basins of auxiliary streams wherever moraine and other deposits are not sharply dissected. Extensive areas of very flat land are generally interfluves separating minor tributaries or smaller strips characterizing flood plains.

[1] Wentworth, C. K., A simplified method of determining average slope of land surfaces: American Journal of Science, ser. 5, vol. 20, 1930, pp. 184-194.

[2] Raisz, Erwin, and Joyce Henry, An average slope map of southern New England: Geog. Rev., vol. 27, 1937, pp. 467-472.



This map differs markedly from one developed by an application of the Wentworth technique to the same area on a strictly statistical basis. Calef has experimented with that method in examining average slopes for 5-minute rectangles of topographic sheets.[3] Results of his experiment were judged by him to be unsatisfactory, as slope conditions on the final map were not an adequate reflection of actual conditions. For example, the map did not reveal the level flood plains of the larger rivers. This map, on the contrary, shows the extent of all large flood plains clearly and reveals that they are very flat. Calef's map suggested but delimited very poorly the areas of dissected steeply sloping lands paralleling the larger rivers. This map delimits such areas far more satisfactorily.

[3] Calef, Wesley, Slope studies of northern Illinois; Trans. Ill. Acad. Sci., vol. 43, 1950, pp. 110-115.

The map presented here therefore represents a radical improvement in method in the delineation of differing terrain regions. There are however, major limitations in the use of this technique, and they may be best illustrated in connection with a consideration of map scale. A major difficulty arises with the mapping of areas characterized by transitional but closely-spaced changes of slope. Such conditions are found southwest of Rockland, where a sizable area has been classified as containing slopes of 5-9 percent. Here the drainage texture is rather closely woven, so that frequent changes appear in the degree of slope. A few flat upland surfaces are sufficiently large and distinct that they can be delimited, but on the whole the 5-9 percent classification represents a rather broad generalization of slope conditions, with more refinement impossible because of the nature of the terrain. An increase in map scale would be of little value, because the areas of transition between slope classifications would tend to be larger than areas falling definitely within one slope classification.

A second difficulty arises in indicating the edges of dissected uplands. The large area of very flat land southwest of Galesburg, designated as 1-5 percent in slope, may be taken as an example. Here the smooth upland surface fuses almost imperceptibly into the gentle slopes of the upper stream valleys. In delimiting the area, therefore, rather pronounced subjectivity must be exercised. An increase in map scale would serve only to magnify the extent of this transition and would not solve the problem.

A third limitation to this method is that of subjectivity. Two workers employing the same set of criteria on a common area will not produce similar results. This differential becomes more pronounced when the terrain is uniform, as the element of subjectivity must be exercised to a greater extent in delimiting such an area.

The position of boundary lines and therefore the general orientation of the finished map depend upon the number and scope of slope classifications which have been subjectively established. Some areas have slopes near the upper or lower limit of a given slope classification. Use of a slope classification system based upon different percentage indices would, of course, alter the size and number of individual delimited areas on the finished map. Nothing substantially would be gained by using the new criteria, however, as there would still be slopes which would just fall within a classification, and the general orientation of the finished map would not differ markedly from that shown here.

In summary, where terrain conditions are quite uniform, the proposed method of representing average slope is unsatisfactory because of excessive generalization of terrain conditions and because the delimiting process is highly subjective. Changing the map scale or the number of slope classifications will not effectively improve the quality of the method in this respect. Where there are sharp breaks between two wholly different areas of terrain, the proposed method is superior in that such divisions can be precisely located on the final map.

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GEOLOGY

ONEOTA FORMATION, STODDARD QUADRANGLE, WISCONSIN

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The Oneota formation, of Lower Ordovician age, is a division of the Prairie du Chien group. For a detailed study of its lower portion, the area selected is the Stoddard quadrangle, in southwestern Wisconsin, along the Mississippi in Vernon and LaCrosse counties. Here the lower part of the Oneota is repeatedly exposed in the upper portion of the Mississippi bluffs, with numerous quarries and natural outcrops also developed up the side valleys and coulees of the dissected Western Upland.

The data on which the study is based consist of detailed descriptions of outcrops and quarries prepared by the writer more than 20 years ago in the course of field work jointly supported by the Wisconsin Geological and Natural History Survey and the Milwaukee Public Museum. Until the present study, these data had not been plotted, nor was the degree of persistence of most of the strata suspected. Field re-examination of the sections in the light of results brought out by the detailed plotting would almost certainly discover additional occurrences of many of the known key beds.

The results in this limited area strongly suggest that lithologic criteria may be employed more widely over the Upper Mississippi Valley for detailed stratigraphic tracing within the lower part of the Oneota. This in turn should permit the establishment of the degree of unconformity of the Oneota base, and have a bearing on the question as to whether the lower, sandy strata of the formation are equivalent to the Gunter sandstone of the Ozark Region.[1] Since the Ozark and Upper Mississippi facies meet in the subsurface areas of Illinois and Iowa, the study has possible applications to practical problems of subsurface correlation, nomenclature, and underground water resources. The wide variety of lithologies indicated suggests that dolomites of different specifications might be commercially recoverable from different parts of the formation.

Oneota Formation

The Oneota formation in the Stoddard quadrangle lies unconformably on the Cambrian, Sunset Point formation, and is overlain by the Lower Ordovician, Shakopee (or Willow River) dolomite, from which it is generally separated by a limited thickness of sandstone strata (new Richmond sandstone). Pre-St. Peter erosion has removed the Shakopee strata over wide areas, however, so

that commonly the St. Peter sandstone contacts some portion of the Oneota.

Lower Oneota Strata

The lower 35 to 40 feet of the Oneota formation comprise a natural unit, which in turn can be subdivided into two consistent members, and these further into a number of distinctive strata, herein designated by the numbers 1 to 9. In all, 15 strata are numerically designated, among which those numbered 1 to 9 are considered primary, those with lower case letters suffixed secondary, and those given prime symbols, of a tertiary category. The first category are those most persistent in occurrence and consistent in position and character.

Strata discriminated are, in descending order, as follows:

Stratum 9. Rather massive dolomite characterized by a broad-domed *Cryptozoon* occurring in masses several feet in diameter; at other localities, massive, cherty to noncherty dolomite without cryptozoa occupies this position.

Stratum 8. A dolomite stratum bearing a *Cryptozoon* packed as columnar colonies 3 to 6 inches in diameter and rising the full height of the bed. Chert is commonly present.

Stratum 7. Fourth green-specked band. Dolomite, coarsely crystalline, vitreous, clean, gray or buff, *studded with glauconite;* floating sand grains present. "Chitons"[2] may occur.

Stratum 7a. A zone of "chitons" commonly underlies Stratum 7. At other localities cryptozoa (No. 7a) are present in this position.

Stratum 6. *Cryptozoon* stratum, packed with columnar colonies, 1 to 2 inches in diameter and rising to the full height of the bed.

Stratum 5. Third green-specked band. Like 7, with "chitons" locally present.

Stratum 4. Zone of abundant "chitons," commonly associated with rather obscure cryptozoa.

Stratum 3b. Locally developed zone of oolitic dolomite.

Stratum 3. Second green-specked band. Like strata 5 and 7, but no "chitons" reported.

Stratum 3a. Locally developed zone of oolitic dolomite, commonly underlain by obscure cryptozoa.

Stratum 3′, 3″. Small (1cm) subspherical pebbles of yellow-green, argillaceous, dense dolomite in matrix of dolomitic sandstone. Probably not a specific stratum but a characteristic lithology which developed intermittently at various levels within a vertical span of several feet.

Stratum 2. First green-specked band. Like Strata 3, 5 and 7.

Stratum 1. *Cryptozoon,* in dome-shaped masses averaging 1 foot in diameter and compounded of closely packed columnar growths. Oolitic dolomite or oolitic chert commonly fills depressions between domes. *Cryptozoon* conglomerate locally occupies this interval.

Stratum 1a. Locally developed oolitic dolomite or dolomitic sandstone.

Oneota base ("B"). A cobbly sandstone conglomerate lies commonly near or at the base of the formation, but the change from fine-grained, well-sorted Sunset Point sand to the coarser, very poorly sorted Oneota sand is the specific criterion of the contact. Strata within the upper few feet of the Sunset Point formation are in places silicified to a semi-quartzite, as in other parts of Wisconsin. Evidence from other areas strongly suggests that this developed in connection with a pre-Oneota erosion surface.

Among the above key lithologies, the various green-specked bands appear to be highly persistent, as are some of the *Cryptozoon* strata (particularly Stratum 6). The "chitons" occur through quite a considerable vertical span of strata, but their most persistent occurrence is in a bed (Stratum 4) directly underly-

[1] Willman, H. B., and Templeton, J. S., Cambrian and Lower Ordovician exposures in northern Illinois: Trans. Ill. Acad. Sci., vol. 44, p. 116, 1951.

[2] The term "chiton" is employed herein to the remains of an organism the shell of which, in curvature and size, is best compared to *Dentalium.* The "chiton" shells, however, are closely septate and only hemi-tubular, being open on one side for the full length of the shell. The reference to "chitons" was tentatively made by E. O. Ulrich (personal communication). Where the shells are abundant, their silicified remains may readily be detected on the vertical face of the bed by means of their crescentic cross sections.

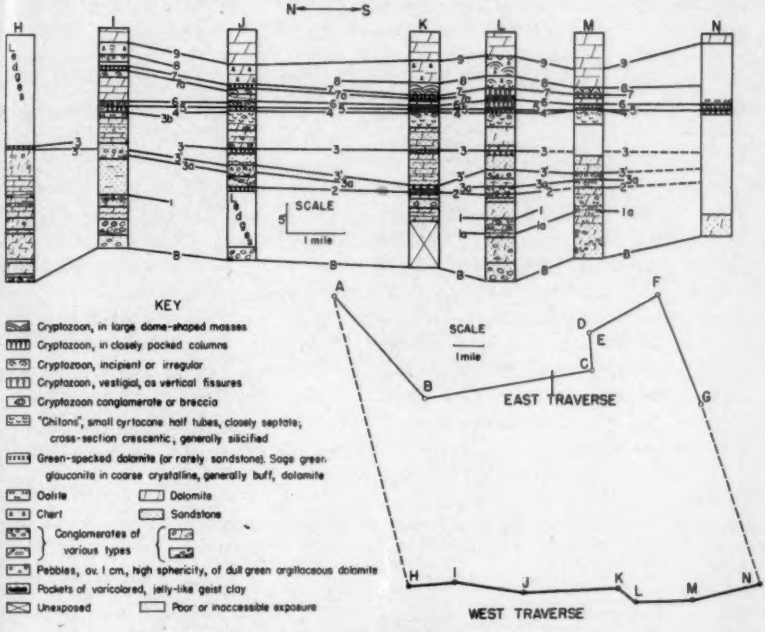

FIG. 1.—Oneota formation, Hickory Ridge and Mound Ridge members. West half of Stoddard quadrangle, Wisconsin.

ing Stratum 5. Oolite, generally in dolomite, is present at nearly all localities, but its persistence in specific strata is less constant than that of glauconite. Chert is even more sporadic in occurrence and is not used for stratal designation; the same may be said for sandstone beds, and for most conglomerates.

HICKORY RIDGE AND MOUND RIDGE MEMBERS

Below the base of Stratum 4 (Chiton stratum) the dolomites are for the most part arenaceous and are interbedded with sandstones, whereas little sand occurs above. On this basis, it seems desirable to divide the unit into two members, the Hickory Ridge below and the Mound Ridge above. Names are taken from physical features in T. 13 N., R. 7 W., Wisconsin, where the type locality is a bluff-top quarry, 1 mile south of Genoa, Vernon Co. (see appended section).

If the member boundary is thus placed, all oolite is confined to the lower or Hickory Ridge member, whereas the "chitons" and most of the chert are confined to the upper or Mound Ridge member. The latter averages 13 feet in thickness, with a range of from 10 to 17 feet; the former 24 feet, with a range of 22 to 26 feet.

Fossils are rare in the Hickory Ridge member, but the trilobite

Symphisurina and small, planispiral gastropods have been found in several areas in Wisconsin. No fossils have as yet been found in the Mound Ridge member.

Genoa Member

Overlying the Mound Ridge member is a stratigraphic section of varied thickness, characterized by strata which are distinctly and evenly bedded, with clean flat bedding planes and smooth vertical jointing. This sequence falls naturally into two divisions, the lower of which ranges from 8 feet in the north to 29 feet in the south. This lower rock unit is light buff, or buffy mottled, commonly in beds 2 to 3 feet thick, which may subdivide under the weather to flagstone dimensions. On the basis of these characters, the unit is called the "buffy bedded zone." Beds are dull in lustre, compact, homogeneous, and generally finely crystalline. Many of the strata are studded with globose, nut-size cavities with facetted walls, which may be lined with dolomite or quartz druse, or solidly filled by white, minutely crystalline quartz. Many beds have zones of horizontal burrows, which are also conspicuous on the bedding planes, where greenish shale partings are commonly present.

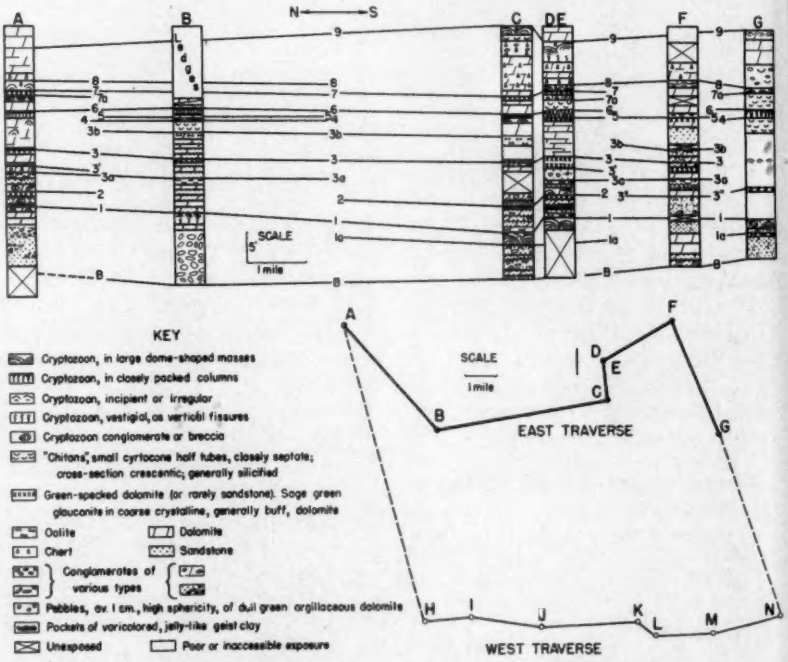

Fig. 2.—Oneota formation, Hickory Ridge and Mound Ridge members. East half of Stoddard quadrangle, Wisconsin.

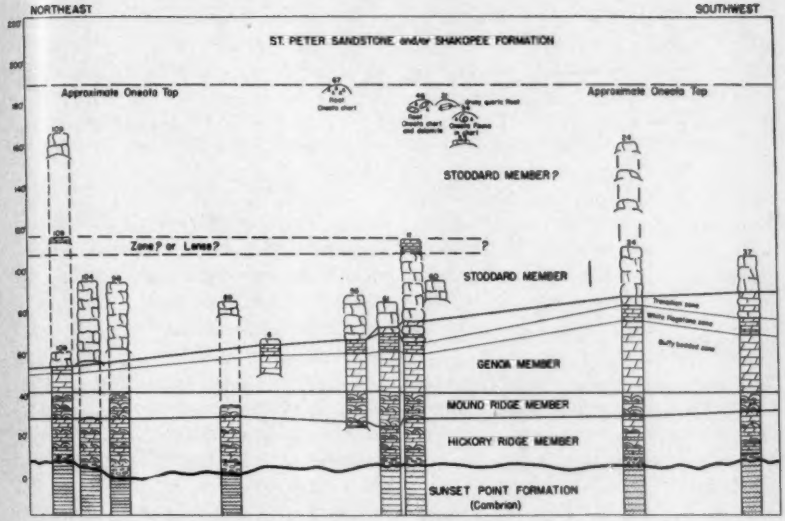

FIG. 3.—Oneota formation, subdivisions. Based on sections related to a line drawn NE-SW across Stoddard quadrangle (lithologic representations are conventionalized).

Chert nodules, in rows parallel to the bedding, occur at a few localities, in the upper part of the unit. Ripple marks were observed at one locality. No fossils were noted.

The higher of the two divisions, the "white flagstone zone," ranges from 3 feet thick in the north to over 8 feet in the south. The dolomite is white, dull, homogeneous, and finely crystalline, and readily breaks to flagstone slabs 2 to 6 inches thick. Nut-sized cavities of the type described in the underlying are generally present; fucoids are scarce or absent, and no chert is reported. Weathering etches out a fine lamination. Dendrites commonly mark the minor joint planes. No fossils have been found.

The white flagstone zone may be directly overlain by massive, rough weathering dolomite of the Stoddard member; or, as much as 12 feet of strata may intervene between the two units. In the main, these strata may be regarded as transitional. Commonly, a few feet of flagstone like the underlying but buff in color will be present at the base, followed by a thicker zone in which these buffy flagstones will be interbedded with Stoddard-type strata. Or, the entire interval may be represented by thick but distinctly bedded buff dolomite, the character of which gradually approaches Stoddard lithology upward. Chert nodules, some of which may be silicified pebbles, occur not uncommonly in this transition zone, in bands parallel to the bedding.

The persistence and relatively constant thickness of the white flagstone zone, in contrast to the varied thickness of the underlying buffy

beds, raises the question as to the presence of an unconformity at the base of the Genoa member. There is, however, no supporting physical evidence. It is quite possible that the buff unit may thicken because of factors other than that of unconformity; moreover, the white flagstone, while continuous lithologically, may not be everywhere contemporaneous. The upward transition of the Genoa member into the Stoddard member seems strongly indicated.

As a result of the variations discussed, the Genoa member ranges from a minimum thickness of 11 feet in the northeast to 46 feet in the southwest part of the quadrangle. The name is taken from the village of Genoa, which lies one mile north of the type locality, which also serves as the type locality for the Hickory Ridge and Mound Ridge members.

Stoddard Member

Above the cleanly bedded, compact, homogeneous strata of the Genoa member, is a massive, rough-weathering dolomite, which may in fact comprise all of the remainder of the formation. Strata of this lithology have been observed to a height of 160 feet above the Oneota base, but the upper beds of the formation are only intermittently exposed on the quadrangle (fig. 3).

The longest continuous exposure of post-Genoa rock was measured in a bluff-top quarry (X 57.11), one mile south of Stoddard, Vernon Co. The 37 feet of rock immediately succeeding the Genoa beds here consist of gray, crystalline-granular, cherty dolomite, massive, virtually without bedding planes, vuggy and traversed by irregular porous areas which cause rough-weathering; the vugs are lined with quartz druses, small calcite rhombs, and marcasite (altered to limonite). Poorly preserved gastropods were noted at several localities.

Above this, at the top of the cliff at the type locality, is a 6 foot thickness of dolomite that is thin-bedded and cryptocrystalline and broken by the weather into small angular pieces 1 to 2 inches in dimension. The only other outcrop of this horizon and lithology is a 2-foot exposure of thin-bedded, homogeneous, medium-grained gray dolomite on U. S. Highway 14 at the north edge of the quadrangle.

Since dolomite and chert of Stoddard type have been found at higher elevations, but in limited exposure, the question naturally arises as to whether the thin-bedded homogeneous strata are local lenses or represent a consistent zone. In the latter case, it may or may not be expedient to designate these beds as a separate member, and to restrict the term Stoddard member to the strata between the thin beds above and the Genoa beds below. Used in this latter way, the Stoddard member would range in thickness from over 50 feet in the northeast to about 25 feet in the southwest part of the quadrangle. Conversely, on the basis of abundant high level chert float of Oneota type, which also yielded Oneota fauna at one place, the member may reach a thickness of over 130 feet.

Strata of Stoddard lithology may be highly fossiliferous, but the fossils have been nearly obliterated by recrystallization of the dolomite, so

that collections are confined to the chert, which has yielded the rich *Gasconadia putilla* Gasconade-Chepultepec fauna of mollusks, with the trilobite *Hystricurus*.

Post-Oneota Strata

Based on actual outcrop, the Oneota formation in the Stoddard quadrangle has a thickness of at least 160 feet, but high-level residual chert of Oneota type, at one locality also with Oneota fossils, suggests an additional 30 feet may be present under the ridge tops, to give a total thickness of 190 feet. This compares not unfavorably with a thickness of 170 feet reported by Kay[3] for Allamakee Co., Iowa, directly across the Mississippi.

At several localities, masses of St. Peter sandstone, which may or may not be in place, were found far below the Oneota top, and at one place, close to the Cambrian contact. This is a common phenomenon in this part of Wisconsin, where the occurrences are such as to suggest that the pre-St. Peter relief was close to the magnitude of the present topographic relief, and that some of the present topography may be exhumed pre-St. Peter topography.

A Platteville outlier rising into the Mifflin member in SW ¼ sec. 34, T. 13 N., R. 7 W., on Mound Ridge indicates the top of the St. Peter sandstone to lie roughly 325 feet above the Oneota base. Topography and chert float indicate that the 135 foot interval between the postulated Oneota top and St. Peter top is occupied in part by that sandstone and in part by Shakopee (Willow River) strata. Whether the New Richmond sandstone is present between the Oneota and Shakopee could not be determined because of inadequate exposure.

[3] G. Marshall Kay, Ordovician system in the Upper Mississippi Valley: Guide Book 9th Annual Field Conference, Kansas Geol. Soc., p. 282, 1935.

Type Sections

HICKORY RIDGE, MOUND RIDGE, AND GENOA MEMBERS

Quarry and Mississippi bluff in NE ¼ SE ¼ sec. 32, T. 13 N., R. 7 W., 1 mile south of Genoa, Vernon Co., Wis.

		Thickness Ft.
Oneota Formation, Stoddard member		
Bed 48.	Grassy slope with a few projecting ledges of dolomite.....	50±
Bed 47.	Dolomite, massive, rough-weathering, full of large to small irregular vugs lined with crystals of quartz and calcite; unstratified except for a few bedded layers toward base; occasional chert nodules, especially near top; indistinct cryptozoa throughout.	29
Oneota Formation, Genoa member		
Bed 46.	Dolomite, single bed, similar to bed 45, but brownish. "Transition zone."	1.7
Bed 45.	Dolomite, like bed 44 but buffy, thicker bedded, with crystal-lined cavities common in lower part. "Transition zone.".....	1.8
Bed 44.	Dolomite, whitish, flaggy, dull, homogeneous, regularly and distinctly bedded, with many nut-size cavities containing quartz and calcite; fine lamination apparent on surfaces etched by weathering; dendrites along joint cracks. Some beds near base have a buffy cast. Top 2 inches is clayey dolomite, weak, finely laminated. "White flagstone zone."...	7.2

Bed 43. Dolomite, light buff, compact, homogeneous, in distinct and rather thick beds, with nut-size cavities lined with small quartz crystals. Top of bed bears abundant "worm" furrows and is studded with broad, flat chert nodules. "Buffy bedded zone." 3.2

Bed 42. Dolomite, light gray mottled with buff, distinctly bedded, homogeneous, somewhat porous, with very few cavities. "Buffy bedded zone." 2.9

Bed 41. Dolomite like bed 38. "Buffy bedded zone." 3.1

Bed. 40. Dolomite like bed 39, but buffy and less rough. "Buffy bedded zone." 2

Bed 39. Dolomite, gray to buffy, compact, massive, rough-weathering, breaking to irregular blocks under the weather; full of drusy cavities and vugs. Lense of small rounded pebble-like bodies at top of bed. "Buffy bedded zone." .....5.5 to 6

Bed 38. Dolomite, light gray, buff weathering, well bedded with beds subdivided under weather; homogeneous, with horizontal rows of nut-sized cavities lined with dolomite druse and calcite rhombs; "worm" furrows prominent on some bedding surfaces, which may also have bluish green shale partings. Some layers have open, horizontal borings. "Buffy bedded zone." 12

Oneota Formation, Mound Ridge member

Bed 37. Dolomite, brownish to purplish gray, granular, in single layer, massive, rough-weathering, studded with nodules of white chert; abundant cryptozoa in large, subglobose colonies compounded of small,closely packed columnar colonies. Silicified "chitons" present in upper part of bed (cryptozoa absent here). Stratum 9..... 3.5

Bed 36. Dolomite, purplish gray, granular, single layer; 6 inch zone in middle traversed by parallel vertical cylindrical openings (vestigial cryptozoa); a few "chitons" in lower part; impure chert in upper part. Stratum 8..... 2.1

Bed 35. Dolomite, resistant, brittle, abundantly specked by glauconite grains in light gray matrix; numerous floating sand grains; small silicified fossils, mainly "chitons," common. Stratum 7. 1

Bed 34. Conglomerate, with pebbles apparent only on weathering; pebbles well rounded, slightly darker than matrix and less compact, maximum size slightly more than 1 inch; matrix compact, purplish gray dolomite..... 0.4

Bed 33. Dolomite, made up largely of cryptozoa in small, columnar, closely packed colonies, which are not everywhere present. Stratum 6. ..... 1.7

Bed 32. Dolomite, crystalline, specked with moss green, clayey glauconite and studded with floating sand. Stratum 5..... 0.4

Bed 31. Dolomite, irregularly porous to compact, with numerous silicified "chitons"; large, subglobose cryptozoon colonies in upper part; basal contact indistinct. Stratum 4..... 2.8

Oneota Formation, Hickory Ridge member

Bed 30. Dolomite, sandy in upper part, brown, crystalline-granular, firm to friable. 2.2

Bed 29. Dolomite, purplish brown, firm, single layer full of large floating sand grains..... 0.7

Bed 28. Dolomite, purplish gray, compact, with occasional glauconite grains. 0.9

Bed 27. Dolomite, gray, finely specked by moss green, clayey glauconite; rock crystalline-granular, homogeneous; single layer. Stratum 3. ..... 0.7

Bed 26. Sandstone, light brown, poorly sorted, with local dolomite cement, and grading upward to dolomite..... 2.4

Bed 25. Sandstone, irregularly dolomitic, with yellow, clay-like pebbles in middle portion. Stratum 3'..... 1.4

Bed 24. Dolomite, sandy (below) and sandstone (above); well cemented. 1.3

Bed 23. Oolite, rather coarse grained and with scant dolomite matrix. Stratum 3a. 1.1

Bed 22. Dolomite, cryptocrystalline, upper few inches mottled by glauconite, lower portion purplish brown; abundant floating sand, very coarse in lower portion. Stratum 2..... 1.5

Bed. 21. Sandstone, white to yellow, medium fine, well-sorted, clean, very friable, laminated, in places cross-laminated..... 1.3

Bed 20. Sandstone, locally dolomite-cemented; locally colored by greenish clay infiltration; local lenses of fine, earthy dolomite with greenish cast. Rock breaks to irregular fragments under weather. 1.2

Bed 19. Dolomite, purplish and buffy mottled, with irregular openings and stylolites; floating sand and oolite grains in about equal abundance, lacking in upper part; rock compact and resistant. Parallel, vertical, pipelike openings at some horibons (vestigial cryptozoa). Stratum 1..... 2.4

Bed 18. Sandstone, dolomitic; coarse grains separated by yellow-brown dolomite, with small oolitic grains abundant; well bedded. Stratum 1a. 0.5

Bed 17. Sandstone, dolomitic, friable to well cemented, with a few small pebbles of yellowish clay; poorly sorted; locally sand-calcite crystals form pisiform concretions..... 4.6

Bed 16. Sandstone, poorly sorted, variously cross-laminated, irregularly cemented, with pebbles of Sunset Point sandstone, which weather away to cavities. Base of Oneota formation... 3.4

Sunset Point Formation

Bed 15. Somewhat interrupted exposure; sandstone, largely in definite, well cemented beds; white, buffy, or brown; fine-grained, laminated, locally cross laminated; horizontal borings common throughout. Basal bed resistant, forming projecting shelf; succeeded by fine, weak, white, saccharoidal sandstone; highest bed subquartzitic, breaking to firm angular blocks under the weather ("clinkstone"). Pebbles in irregular lenses near base; mudcracks in the weak, white sandstone. 17.7

Bed 14. Sandstone, poorly sorted, weak, dirty, variously cross-laminated, commonly with adjacent laminae of green shale and coarse sand. Pebbles present near top. Upper surface covered with large "wave" ripple marks, about 1 inch high and 4.5 inches apart; rippled surface traversed by furrows of crawling animals. Unconformity at base has a relief of 12 inches. .....Mean, 3.5

Trempealeau Formation, Jordan member

Bed 13. Sandstone, medium to coarse grained, grains rounded, frosted; clean, porous without fine fractions, except for occasional partings of resistant shale which weather in relief; cross-bedded with bedded units having steep foresets of constant direction, prevailingly northwest; no bedding planes, but an alternation of thick, steeply and gently cross-laminated zones, the complex itself having a northerly inclination. Sand basically white and friable but brilliantly stained by ochre. Van Oser submember. .....Mean, 16.5

STODDARD MEMBER

Quarry and Mississippi bluff in NW ¼ NE ¼ sec. 33, T. 14 N., R. 7 W., 1 mile south of Stoddard, Vernon Co., Wis.

Oneota Formation, Stoddard member (?)
Dolomite, thin bedded, cryptocrystalline, broken by weather into angular chips 1 to 2 inches in diameter 6

Oneota Formation, Stoddard member
Dolomite, massive, almost without bedding, gray, crystalline granular, compact to porous, vuggy with linings of drusy quartz or rhombic calcite, and less commonly marcasite (limonite pseudomorphs); chert nodules; poorly preserved molds of gastropods 37

Oneota Formation, Genoa member
Transition zone 11.7
White flagstone zone 4.9
Buffy bedded zone 12.4

Oneota Formation, Mound Ridge member
including development of Strata 4, 5, 6, 7, 8, 9 ..... 12.4

Oneota Formation, Hickory Ridge member
including development of Strata 1, 3a, 3', and 3b 22.3

Sunset Point Formation 24.3
Trempealeau Formation, Jordan member
Van Oser submember 14.5

Localities

(Letters and numbers to left correspond to those on charts)

A. Locality 101; center of NW ¼ sec. 7, T. 14 N., R. 5 W.; 1 mile WNW of Coon Valley, Vernon Co.

B. Locality 89; SE ¼ NE ¼ sec. 28, T. 14 N., R. 6 W.; bluff rising above railroad station, Chaseburg, Vernon Co.

C. Locality 61; NE ¼ NE ¼ sec. 27, T. 13 N., R. 6 W.; ravine 1 mile SW of Newton, Vernon Co.

D. Locality 55; SE ¼ SE ¼ sec. 23, T. 13 N., R. 6 W.; quarry on County highway, 1 mile ESE of Newton.

E. Locality 57; NW ¼ NW ¼ sec. 25, T. 13 N., R. 6 W.; ravine west of county highway, 1.5 mile ESE of Newton. (locs. 55 and 57 are combined as a composite section).

F. Locality 50; SE ¼ NW ¼ sec. 6, T. 12 N., R. 5 W.; ravine above bridge on west side of Norwegian Hollow, Vernon Co.

G. Locality 41; SE ¼ SE ¼ sec. 9, T. 12 N., R. 6 W.; bluff on north side of South Fork, Bad Axe River, Vernon Co.

H. Locality 7; west half SE ¼ sec. 21, T. 14 N., R. 7 W.; Mississippi bluff at north edge of Stoddard, Vernon Co.

I. Locality 11; NW ¼ NE ¼ sec. 33, T. 14 N., R. 7 W.; quarry in Mississippi bluff, 1 mile south of Stoddard, Vernon Co.

J. Locality 15; NE ¼ SW ¼ sec. 9, T. 13 N., R. 7 W.; McDonald's Quarry, Vernon Co.

K. Locality 30; NE ¼ SW ¼ sec. 28, T. 13 N., R. 7 W.; ravine ½ mile west of Genoa, Vernon Co.

L. Locality 24; NE ¼ SE ¼ sec. 32, T. 13 N., R. 7 W.; quarry 1 mile south of Genoa, Vernon Co.

M. Locality 28; SW ¼ NW ¼ sec. 9, T. 12 N., R. 7 W.; Mississippi bluff, 1 mile north of mouth of Bad Axe River.

N. Locality 37; NW ¼ SE ¼ sec. 21, T. 12 N., R. 7 W.; Mississippi bluff, 1.5 miles south of mouth of Bad Axe River.

6. NW ¼ NW ¼ sec. 15, T. 14 N., R. 7 W.; quarry on road ascending bluff 2½ miles NNE of Stoddard, Vernon Co.

11. equals "I."

21. NW ¼ sec. 13, T. 13 N., R. 7 W.; road at head of Spring Coulee, Vernon Co.

24. equals "L"

37. equals "M"

46. SW ¼ SE ¼ sec. 7, T. 12 N., R. 5 W.; knoll rising above elevation 1,200', on Nottingham Ridge, Vernon Co.

53. SE ¼ SW ¼ sec. 2, T. 12 N., R. 6 W.; ledge at bend of ridge road, 1.5 miles south of Plainview School, Vernon Co.

54. SE ¼ NE ¼ sec. 3, T. 12 N., R. 6 W.; in ravine 0.2 miles south of State Route 56, 1.5 miles southwest of Plainview School, Vernon Co.

55. see "D"

60. NE ¼ NW ¼ sec. 20, T. 13 N., R. 6 W.; bluff ¼ mile west of mouth of Wire Hollow, Vernon Co.

61. equals "C"

67. SW ¼ NE ¼ sec. 30, T. 13 N., R. 5 W.; ridge top 1.2 miles NNW of White Pigeon School, Vernon Co.

89. equals "B"

98. NW ¼ SE ¼ sec. 19, T. 14 N., R. 5 W.; bluff on north side of valley, 2 miles south of Coon Valley, Vernon Co.

104. NE ¼ NW ¼ sec. 11, T. 14 N., R. 6 W.; on U. S. Route 18, 2½ miles west of Coon Valley.

109. SE ¼ SE ¼ sec. 29, T. 15 N., R. 6 W.; on U. S. Route 18, descending from Brinkman Ridge to Mormon Coulee, LaCrosse Co.

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ENVIRONMENTAL CONTROL OF IRON MINERAL DEPOSITION

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Many iron formations, including those of pre-Cambrian and of later ages, are generally believed to be of sedimentary origin. Many differences of opinion have arisen, however, as to the source of the iron for these deposits, the nature of the transporting medium, the nature of the depositional environment, and the primary minerals in the deposits.

Assuming that the high iron content of these formations is primary, it is possible that the present iron mineralogy represents to a large degree that of the original deposit—at least in the unmetamorphosed or only slightly metamorphosed areas. Many of these deposits can be divided into distinctive facies on the basis of their iron mineralogy. For example, Harold L. James has divided the pre-Cambrian iron formations in the Iron River district of Michigan into an iron sulfide, an iron carbonate, and an iron silicate facies, each of which he believes represents the primary iron mineralogy of that part of the deposit (James, 1951). If this is so, the present iron minerals should reflect the chemical environment of their original deposition.

One line of approach that might help in answering some of the problems concerning these environments is a study of the relations between equilibrium mineral associations that would be expected under postulated conditions of primary sedimentation, and the mineral associations actually observed in the field. Besides indicating the degree of equilibrium of the field relationships, such a study might shed some light upon the problems of the transportation of iron, the nature of the terrain from which the iron was obtained, and other problems concerning the genesis of iron formations.

Eh-pH Stability Fields

The depositional environment of minerals precipitated from surface waters can be considered to have essentially constant temperature and pressure. In many such natural systems the chemical reactions involved may be characterized almost entirely by the hydrogen ion concentration and the oxidation-reduction potential, Eh, of the environment (Krumbein and Garrels, 1952). By considering the Eh and pH relationships of a postulated environment, the various mineral associations can be predicted and their fields of stability plotted on an Eh-pH diagram comparable to a temperature-pressure diagram. The assumption must always be made that the various minerals present in a given environment are in equilibrium with that environment. With some exceptions, the close agreement between expect-

ed mineral associations and observed field relationships indicates that natural systems are essentially equilibrium systems.

The Eh-pH stability fields have been calculated for hematite, siderite and pyrite in normal sea water and are shown in figure 1. They indicate that hematite is stable and will precipitate in oxidizing environments, siderite in intermediate or slightly reducing environments, and pyrite in strongly reducing environments. A position within any of the stability fields indicates that the activity product of only that mineral is exceeded and it will precipitate to the exclusion of the other minerals on the diagram. Furthermore, a mineral if moved from its stability field, by a change in Eh-pH conditions, to a field in which it is unstable, will tend to go back into solution or change in composition until equilibrium is again reached. The field boundaries for these iron compounds are essentially independent of the concentration of the components. For example, since the ferric-ferrous ratio is constant at a given Eh, increase in total iron would increase the amount of siderite or hematite precipitated but would not cause a change from siderite to hematite. A change in precipitation from one mineral to another will not take place unless there is a change in the Eh or the pH of the environment.

A series of experiments were conducted in which iron in the ferrous state was introduced into various Eh-pH environments (Huber, 1952). The experimental work indicated that hematite and siderite actually will precipitate under the predicted

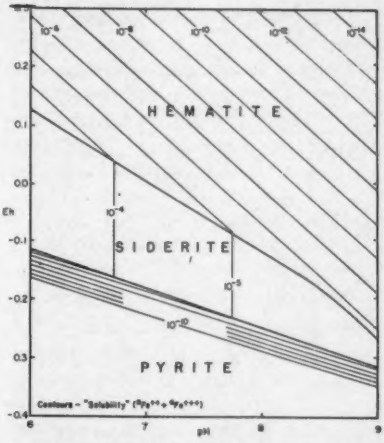

FIG. 1.—Eh-pH stability fields for hematite, siderite, and pyrite in sea water.

environmental conditions. The experiments also contributed to the evidence that sulfate cannot be reduced to sulfide in a strictly inorganic system, and therefore indicate the necessity of sulfate-reducing bacteria or other organic agents for the formation of pyrite. Regardless of organic activity, however, pyrite is not stable and cannot be formed unless the Eh-pH conditions lie within the pyrite stability field. The experimental work, therefore, supports the validity of predicting mineral occurrences on the basis of Eh-pH stability diagrams.

TRANSPORTATION OF IRON

One of the major problems in considering the genesis of iron formations is the transportation of iron to the depositional basins. Among the factors to be considered are the amount of iron that can be carried by streams and the state in which the iron is carried.

Iron can be carried in significant quantities in true solution only under rather restricted conditions. Reference to the solubility contours on the Eh-pH stability diagram shows that the conditions under which one part per million or more of iron ($>10^{-5}$ moles/liter) can be carried in true solution to be a pH of 7.5 or less and an Eh ranging from $+0.2$ to -0.15. Natural fresh-water streams are on the average neutral or slightly acid and thus satisfy this part of the environmental requirements. However, only under conditions of oxygen deficiency can the Eh requirements be met. It is possible that slow-moving, partially-stagnated streams draining noncalcareous terrain would have a great enough oxygen deficiency to carry large quantities of iron in true solution.

Iron carried in colloidal form is not subject to the same Eh-pH requirements as iron carried in true solution, and it is believed that most streams carry more iron in this manner than in true solution. However, in order to form extensive clastic-free iron deposits some mechanism must be provided to separate this iron from other colloids including clay minerals.

Deposition of Iron

Upon reaching a body of water, such as a marine basin, the iron in the streams emptying into that body of water will tend to conform with the new environmental controls imposed upon it. In marine waters the iron will be virtually completely precipitated and the iron minerals formed will depend upon the Eh and the pH of the environment.

Hematite should be precipitated if the environmental conditions are within the hematite field of stability, such as in a well-aerated basin, shallow enough to allow waves and currents to keep the water well-oxygenated. Ripple marks and oolites in some of the hematite beds are evidence of this type of an environment.

Siderite should precipitate if the environmental conditions lie within its stability field. The Eh limits of this environment vary somewhat with pH, but in the range from pH 7 to pH 8, which is likely in marine environments, conditions are moderately reducing, becoming more reducing with increasing pH. Such an environment might occur in a restricted basin deficient in oxygen. An environment slightly more acid than normal sea water would cause formation of siderite rather than calcium carbonate.

The environment under which pyrite is stable is one of moderate to strongly reducing conditions. However, as the reduction of sulfate is negligible in a low-temperature inorganic system, sulfate-reducing bacteria or some other agent producing hydrogen sulfide appear to be necessary for the formation of pyrite. Thus the optimum conditions for the formation of pyrite require a highly restricted anaerobic environment, such as a stagnant lagoon or euxinic basin.

Summary and Conclusions

In summary, a study of the theoretical and experimental relations between equilibrium iron mineral associations indicates that the environmental conditions for the primary

deposition of these minerals can be delineated by Eh-pH stability fields.

Several general conclusions can be drawn from this study:

1. The experimental work shows that hematite and siderite precipitate under conditions predicted from Eh-pH stability relations.

2. The experiments also contributed to the evidence that sulfate cannot be reduced to sulfide in an inorganic system at low temperatures, and therefore indicate the necessity of sulfate-reducing bacteria or other organic agents for the formation of pyrite.

3. Iron can be carried in true solution in quantities greater than one part per million only under restricted conditions; pH of 7.5 or less and Eh values from + 0.2 to — 0.15.

4. Fresh-water streams, which on the average are neutral or slightly acid, can carry significant quantities of iron in true solution only if they are so deficient in oxygen as to maintain Eh in the range + 0.2 to — 0.15.

5. Present tropical streams carry large quantities of iron. If the streams are well aerated the iron must be carried colloidally. If the streams are partially stagnated iron can be carried in significant quantities in true solution.

6. If iron is carried colloidally, some mechanism is necessary for the separation of this iron from other colloids, such as clays, in order to form clastic-free iron formations.

7. Finally, it is suggested that iron made available by weathering processes and transported by slow-moving, partially stagnated streams, especially under humid-tropical or humid-subtropical conditions, is sufficient to form extensive iron-rich deposits. The iron minerals formed depend upon the immediate depositional environment rather than the form in which the iron is transported. The major factors controlling the minerals formed are the Eh and the pH of the depositional environment.

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SOME NEW OBSERVATIONS ON NIAGARAN REEFS IN ILLINOIS

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A number of subsurface reefs have been discovered recently near the southern border of the Niagaran reef archipelago of Illinois and Indiana, in the frontal or deep-water portion of the archipelago. Studies of cores and cuttings from wells in these reefs and from a recently deepened well in one of the earlier-known reefs, together with continued examination of the outcropping reefs of the Great Lakes area, have contributed to a clearer understanding of the development of these fossil reefs.

This report supplements earlier descriptions of the Niagaran reef archipelago (Cummings and Shrock, 1928; Lowenstam and Du Bois, 1946; Lowenstam, 1948, 1949, 1950; the first and last papers contain lists of other pertinent literature). The new data shed light on the composition and dynamic history of the horns of the horseshoe-shaped Marine reef, the significance of oolites among the reef rock types, the relation of reef size and spacing, the cyclical nature of many reef-flank beds, and the agent which molded the present upper surface of the buried reefs.

The Marine subsurface reef in Madison County has been a source of continued interest (Lowenstam and Du Bois, 1946; Lowenstam, 1948, 1949, 1950). The similarity of its horseshoe outline to certain present-day reefs on the Sunda and Queensland shelves has been noted. This similarity is most striking with certain "inner" reefs of the Queensland area recently illustrated by Fairbridge (1950). Umbgrove (1930) has shown that similarly shaped present-day reefs are characteristically formed in the unobstructed path of the prevailing winds following emergence of the initial upgrowth from deeper waters into the wind-agitated surface water. The wind-swept horns are made up of the bioclastic debris that has been winnowed from the frontal growth center. In accordance with this concept, prongs projecting northward from Marine reef were interpreted by the writer as wind-swept horns. This interpretation seemed reasonable on the basis of shallow wells encountering solely bioclastic debris, but it was weak in that there was no information on reef composition at depth.

The cable tool deepening of the Kingwood No. 4 Appel, NW ¼ SW ¼ NW ¼ sec. 9, T. 4 N., R. 6 W., penetrated the west prong of the Marine reef near its attachment to the main reef body and provides an opportunity to test the soundness of the interpretation The deepening started at 1758 feet, 31 feet below the top of the reef, and penetrated

in succession 447 feet of reef lithologies, 8 feet of reef-modified Moccasin Springs deposits, 38 feet of normal St. Clair limestone. The reef rocks can be described in three units, the upper consisting of 155 feet of calcitic bioclastic debris with a 24-foot thick oolite-bearing section 18 feet above its base. This essentially dolomite-free unit is underlain by 193 feet of calcitic bioclastic debris with varying proportions of rather dense dolomite, the dolomitic content increasing irregularly downward. The basal unit is 99 feet of reef-type, porous, permeable dolomite.

The bioclastic debris character of the uppermost, essentially undolomitized section is clear cut. The debris is dominantly crinoidal, such other elements as bryozoan fragments, tabulate corals including *Favosites* and *Striatopora*, stromatoporoids, and brachiopods including recognizable fragments of *Conchidium* increasing in abundance with depth. At certain levels brachiopods may make up as much as 60 percent of the rock.

The limestone portions of the middle section have identical biologic composition, but no fossils were recognized in the dense dolomitized portions or in the lower porous dolomite. The question arises as to whether the basal dolomite section constitutes a dolomitized reef-core section, that is, a building center, which gave way in time to bioclastic accumulation through an intermediate transition zone in which the reef-building sections had been selectively dolomitized.

To come to a satisfactory interpretation, it should be noted that the reef section is underlain by an 8-foot layer of greenish-gray, slightly argillaceous, mostly silty, calcitic dolomite with pink to ferruginous crinoidal remains, which represents basal Moccasin Springs strata. It differs from the typical basal Moccasin Springs lithology, which is very silty and commonly deep red, and it constitutes, by comparison, a carbonate-enriched sediment in which the regionally oxidized terrigenous muds have been reduced by the decomposition of a higher organic content. It is similar to the modified Moccasin Springs sediments encountered underneath the reef deposits in the two wells which penetrate other portions of the Marine complex, the Eason No. 1 Mayer and the Ryan No. 1 Kissner (Lowenstam, 1948).

These atypical rocks are interpreted as resulting from deposition in the turbulent area surrounding the initial reef center. Later these beds were overlapped by the expanding reef. In the Kingwood No. 4 Appel these modified Moccasin Springs sediments are only 8 feet thick as compared to 60 feet in the Ryan No. 1 Kissner and 35 feet in the Eason No. 1 Mayer. These thicknesses correlate with the geographic positions, for the Appel well is much closer to the central portion of the mature reef where the initial growth center is postulated. With expansion of the reef toward the location of the Kingwood No. 4 Appel, the first actual reef material deposited at that point should logically be fine reef outwash, becoming progressively coarser with decreasing distance from the reef border proper. Eventually the debris fan or portions of it might become fixed by incrusta-

tion with reef-building organisms, though such fixing would be least likely on an actively expanding wave-swept tongue. Here debris would accumulate rapidly and the likelihood of migration by shifting winds would be greatest. In the light of such an interpretation, the basal portions should be composed of finer reef outwash, the transition zone of a progressively coarser fraction, and the top non-dolomitized portion of coarse debris only.

The selective dolomitization of fine interstitial carbonate enclosing coarser calcitic skeletal remains has been demonstrated by Johnson (1951, ms.). One example is in upper Joliet dolomitic limestone of the St. Clair type at Naperville in northeastern Illinois. This data clearly indicates that fine carbonate debris tends to be replaced first during dolomitization. Therefore the well section under discussion is interpreted as representing solely a succession of bioclastic debris, the initial finer fraction of which became dolomitized. It corroborates the previous interpretation that the horns of the Marine reef are composed of bioclastic debris winnowed by waves. It strengthens the interpretation that Marine and other Niagaran reefs of the area had wave-resistant growth stages and were comparable in form and mode of formation to present day reefs.

The oolitic zone in the Marine reef penetrated by the well deepening is of particular interest because it is the first record of oolites in the low clastic belt associated with a reef. A second oolite occurrence has since been found by the writer at Thornton reef, south of Chicago. Cross-bedded, well-sorted oolites of different sizes have been found in a large, loose block composed of sorted bioclastic debris, located in the southern part of the exposed reef flank in the old south quarry. The fossils, debris, and sorting leave little doubt that the enclosing oolite bands were deposited on the southern reef flank and imply derivation from the reef surface. The oolites at both the Marine and Thornton reefs, nonexistent in interreef areas and previously unknown outside the clastic-free, shoal-water belt to the northwest, are corroborating evidence of the wave-resistant nature of the Niagaran reefs.

The size and shape of Niagaran reefs varies considerably. The Marine reef, with an areal extent of about 6 square miles is the most extensive reef known in the Niagaran archipelago. The numerous reefs discovered in recent years in the southwestern frontal area of the archipelago seem similar in area to those fringing the Bainbridge basin from the Vermilion County embayment southward through eastern Indiana. Most are a few tens of acres to a little over a square mile in area. A high reef density seems to go hand in hand with comparatively small size in both frontal segments of the archipelago. The large Marine reef lies some distance inside the archipelago. No form comparable to Marine reef and no back-swept prongs of any sizable extent have been recognized in the frontal reefs.

The area surrounding Marine reef has been tested over a considerable radius, and it is not likely that other reefs of any size are nearby. This view is further corroborated by the

comparatively undisturbed sedimentary succession in the interreef area beyond the zone of turbulence, best illustrated by the St. Jacob's oil pool where closely spaced wells provide detailed cross sections. It thus appears that the larger area of Marine reef, as contrasted with that of frontal reefs, can be attributed partly to its isolation. The smaller frontal reefs were not similarly exposed to winds and waves because they were close together and partially shielded one another. Possibly there was also greater competition for planktonic food in the frontal area.

The isolated position of the Marine reef explains its more vigorous growth and production of bioclastic debris in quantities great enough to build its larger apron with backswept horns. This explanation, nevertheless, is insufficient to account for the apparent lack of distinct backward-curved accumulations of debris on frontal reefs, particularly on those like Bartelso, which are the ribbon type of Fairbridge (1950). Bartelso has a long axis facing the basin margin, and was totally unprotected from waves and swells sweeping northward from the basin.

An explanation for this phenomenon may be found in the fact that the frontal reefs were growing on the actively subsiding rim of the Bainbridge basin. This is evidenced by their overall height, which reaches 1000 feet in the Sandoval reef. These reefs rose from considerably deeper bottoms, even in the later phase of decreased subsidence, than did Marine reef.

The substrate of the Marine reef early became incorporated into the basin shelf margin. Hence the reef developed during most of its later history in comparatively shallow water, though its substrate remained constantly below effective wave base (Lowenstam, 1950). After attaining resistance to waves, Marine reef could expand peripherally, with resultant rapid buildup of an impressive detrital apron. The horseshoe shape of the apron resulted from the channeling action of waves on the leeward side of the reef.

In contrast, the frontal reefs would grow principally upward to maintain contact with the water surface, and winnowed bioclastic debris would be lost to the peripheral deeps. It would also take a considerably longer period of time to build up debris accumulations to water level on the steep slopes.

Thus tectonic control, water depth, and density of spacing seem to be recognizable factors in the environmental control of the reefs. Similar conditions are found on the present Queensland shelf. If this interpretation is correct, there should be other large reefs comparable in size to the Marine reef some distance to the northeast, in Bond County, for instance, though none have yet been found. Similarly, the depth of this belt of widely separated large reefs, if it extends over any distance, remains to be determined. Our knowledge of reef density and spacing in the low-clastic belt to the northwest and northeast is limited largely to isolated areas such as the Chicago region and the Wabash valley area of Indiana. Cumings and Shrock (1928) show a considerable density of comparatively small reefs in the so-called Mississinewa shale in the

Wabash area. Larger reefs apparently more widely spaced are found higher in the section in the Racine-Guelph interval.

Comparative studies of reef-flank beds around many outcropping reefs in the low-clastic belt and a few in the clastic-free belt, have demonstrated that, although they may be composed largely or partly of bioclastic debris, considerable portions may contain terrigenous clastics or even typical interreef sediments. The rigidly welded frameworks of reef-building organisms together with entrapped sediments also may account for a large part.

As indicated by the presence or dominance of bioclastic debris and by inclined radial dips away from the reef-growth centers, the reef flank is a definite peripheral, topographic component of the reefs. To allow the formation of such a distinct flanking element, it was necessary that the reefs actually had topographic expression and that the sea bottom bordering the reef was at quiet-water depth throughout reef development. Hence, reef flanks developed principally in the clastic belt. Formation of flank beds, however, could not begin until the phototropically expanding reef surface reached turbulent surface water, and did not attain volumetrically significant proportions until after wave resistance had been attained. The range in components of reef-flank beds, as well as their shifting ratios, can thus be understood in terms of the depth stage at which the reef flanks were formed, the location of given reef-flank elements with reference to the prevailing wave direction, and micro-environmental differences due to topography on the expanding flank. At the wave-resistant stage, mechanically worn bioclastic debris from the expanding reef mass should be a major constituent, if not the principal one, of the reef flanks.

Of all the evidence to demonstrate that at least some of the Niagaran reefs attained wave resistance, an obvious one is the composition of the reef flank at this growth stage. In a previous analysis (Lowenstam, 1950), this line of evidence was little explored. Although it was shown that the reef-flank deposits at this stage were principally fragments of reef-inhabiting organisms and displayed a high degree of sorting, there remained the question of which proportions were derived from flank-dwelling organisms rather than from the reef surface, a point further emphasized by the comparatively low incidence of mechanically broken and worn skeletal debris. Recent studies of the flanks of reefs in the Chicago region at Thornton, at McCook one mile southeast of LaGrange, and about two miles south of Manteno, all of which had been interpreted previously as formed at the wave-resistant stage, have brought to light additional data.

There is an orderly, distinct, cyclical development in the succession of components which make up the exposed reef-flank sections in all these localities. The most conspicuous and persistent member of this multicyclical development consists of coarse bioclastic debris. It may alternate with either dense, structureless, high-purity dolomite that contains varying amounts of larger fossil remains, or with layers of the

FIG. 1.—Cyclical reef-flank deposits consisting of alternating layers of coarse bioclastic debris (dark) and dense, structureless dolomite (light) in the south flank of Thornton reef in north portion of old (south) quarry of the Material Service Company, Thornton, Ill. *Upper left.*—Cyclical deposition in flank portion brought out through weathering; dark layers consist of bioclastic debris. *Upper right.*—Closeup of two coarse bioclastic debris layers with alternating dense dolomite, northeast of section shown in first picture. *Lower left.*—Cycles farther from the reef core south of those shown above. *Lower right.*—Closeup of portion above hammer shown at left.

rigidly welded skeletons of resistant frame-builders such as *Stromatactis*-like forms, stromatoporoids, or sheety, tabulate corals, with various entrapped materials. A third member may be represented by material that ranges from slight admixtures of terrigenous clastics with bioclastic debris and with fine carbonate all the way to normal, quiet-water, argillaceous interreef lithologies. Layers entirely composed of oolites form a fourth, rarely developed, member.

At Thornton, where the entire eastern half of the reef-flank section and its relations to the easternmost reef cores are now fully accessible for observation, the flank sections

closest to the reef core consist principally of cycles composed of thin alternations of reef-builder layers with coarse bioclastic-debris beds. The section at moderate distances from the core consists largely of alternations of dense layers with coarse bioclastic debris (fig. 1), and the outermost flank portion consists of the same members with the addition of an argillaceous component. Oolite layers intercalated with dense bands are probably confined to the south-central portion of the flank as numerous loose blocks in which they occur have been found only there.

At Manteno and McCook the reef cores are not exposed. The observable flank sections at Manteno consist of alternating coarse bioclastic debris and fine dense dolomite layers. At McCook the flanks consist in part of a triple succession of the same two members with the addition of a fine layer or film of argillaceous dolomite.

Piecing together the data at hand, it appears that, following attainment of wave resistance by an upward-growing reef, the reef flank expanded initially by means of intermittent blanketing by reef-derived fragments. This debris subsequently was stabilized through reoccupation by reef builders. As the flank expanded peripherally it must have acquired a terrace-like form, bounded at the top by the depth of effective surf action which allowed only lateral expansion. Increase in expanse of the reef surface, particularly of the flank terrace, provided more area to be covered by reef builders and then an increasing volume of bioclastic debris. The increased volume of wave-reduced bioclastic debris, in the form of fine grains, migrated across the outer terrace edge during comparatively calm conditions, reduced the numbers of reef-building organisms, and finally prevented them from occupying the flank slopes.

Sweeping of the growth area and terrace surface during heavy storms carried great volumes of bioclastic debris and torn-off sessile benthos to the terrace edge to be dumped downslope. Stirring up of the finer fraction upslope during such processes led to resettling downslope toward the end of the storms. Further expansion of the terrace must have finally carried the slope edge past the area of intense surf, thereby allowing, during calm intervals, the settling of the suspension fraction, including terrigenous muds. During storms, the terraces became intermittent sites of coarse debris accumulation. Stirring up and resettling of the fines must again have taken place during storm periods, particularly upslope. Indigenous flank dwellers evidently contributed to the accumulations during all stages of the flank evolution.

The cyclical formation of the flank beds raises the question of whether we are dealing with annual varving or phenomena of longer duration. The volume of individual coarse bioclastic debris layers speaks against a yearly cycle, as it would require a productivity in terms of yearly overall carbonate synthesis and death rates which appears out of proportion to present-day analogues. A hundred-year cycle, however, based on the frequency distribution of exceptionally heavy storms, similar to those noted in connection with investigations of river-flood controls,

would satisfactorily account for the coarse bioclastic debris layers. Detailed data and their implications are presented elsewhere. The developmental mechanics of the flanks of these three reefs corroborate the contention expressed previously that these particular reefs were wave-resistant.

In this connection, it seems equally significant that the bioclastic debris in cores of nondolomitized subsurface reefs contains a larger proportion of mechanically fragmented skeletal remains of stromatoporoids, tabulate corals, and, in particular, of bryozoa, than can be recognized in the recrystallized dolomitized outcropping reefs. Also, the consolidated nature of sorted and partly rounded bioclastic debris found in blocks of the storm conglomerate at Thornton, denoting mass destruction on the Thornton reef by a storm of hurricane violence, constitutes another line of evidence that the Thornton reef acquired wave-resistance. Consolidation through cementation of bioclastic debris is a common phenomenon of beach rock exposed between tides on wave-resistant reefs today. The similarity in graded and sorted debris in the Thornton blocks to present-day beach rock is striking.

The last aspect to be considered pertains to the surface topography of buried reefs. Is there some remnant of the original relief or has the surface been totally modified by post-Silurian erosion? At the Marine reef, which is covered by middle or late Devonian deposits, the isopach map of the Wapsipinicon suggested modification of the original surface relief (Lowenstam, 1948) by pre-Devonian erosion. The frontal reefs which skirt the Bainbridge basin to the northwest, are mantled by New Albany shale, and hence were exposed over a longer time than even Marine to sub-aerial erosion. Frontal-growth centers, originally higher than their leeward accumulations of bioclastic debris, save for possible "sand cays," commonly are lower now, a fact which implies strongly that the surface topography has been greatly modified by subsequent sub-aerial erosion. Therefore only the outline pattern and not the detailed topography of such reefs as Marine can be relied upon for comparison with present-day reefs.

The writer is indebted to Drs. Francis J. Pettijohn and K. O. Emery for suggestions incorporated in the interpretation of the periodicity length in the cyclical flank deposition and the beach rock recognition, respectively.

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THE CHOUTEAU FORMATION OF ILLINOIS*

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The Chouteau formation of Illinois is a distinctive limestone of early Mississippian age which underlies most of the southern half of the state. It is commonly 10 to 30 feet thick. The formation crops out along the western edge of Illinois in Jersey and Calhoun counties; from there it dips to 4500 feet below sea level in the center of the Illinois basin. Stratigraphic variations, criteria for subsurface recognition, distribution of silt and dolomite, and lateral changes in color are described in this study.

The writer wishes to express his gratitude to L. E. Workman, formerly on the staff of the Illinois Geological Survey, and H. B. Willman, E. Atherton, and D. Swann of the Illinois Geological Survey, and to Jack L. Hough, of the University of Illinois, for their advice and assistance.

Previous Studies

Swallow (1854, pp. 101-102) named the formation for Chouteau Springs, Cooper County, Mo. Near this town he described a 70-foot section of 40 feet of brownish-gray earthy thick-bedded dolomitic limestone which grades downward into 30 feet of fine-grained compact thin-bedded fossiliferous limestone. Meek and Worthen (1861, p. 167) called an eastern exposure of this limestone the "Rockford goniatite bed" after an outcrop near Rockford, Jackson County, Ind. They reported several species of fossils from this bed to be identical to those found in the Chouteau formation of Illinois and Missouri. Kindle (1899) modified "Rockford goniatite bed" to Rockford limestone. Moore (1928, p. 33) suggested restricting the term Chouteau to the lower portion of Swallow's section. He proposed the named Sedalia for the upper magnesian portion. Workman and Gillette (1947) drew an isopachous map and showed by cross sections that the Chouteau and Rockford are the same formation. Branson (1944, pp. 189-208) did not recognize Moore's subdivision of the Chouteau. He considered the Sedalia and Weller's (1909, p. 265) Fern Glen formation to be members of the Chouteau formation. In Illinois the Chouteau limestone is considered the uppermost formation in the Kinderhook group.

Sources of Data

In the present study, microscopic examinations of sample cuttings of the Chouteau from approximately 500 wells which penetrate the formation in Illinois were made to determine thickness, depth, and lithology. Electric logs, drilling-time logs, or radioactivity logs are available for many wells, and these were compared to determine accurate thicknesses and depths of the Chouteau limestone.

Twenty outcrops in Jersey, Calhoun, and Pike counties of southwestern Illinois and in Pike, Lincoln, and St. Charles counties of

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eastern Missouri were visited, and 138 representative samples were studied in the laboratory. Insoluble residues of all the samples were also studied.

The thickest exposure of Chouteau in Illinois crops out in Jerseyville Hollow, Jersey Co., NE ¼ sec. 10, T. 6 N., R. 12 W., where 55 feet of Chouteau is exposed. There it is overlain by Burlington limestone and underlain by Hannibal siltstone and shale.

In the bluffs of the Mississippi River, near Chautauqua, Jersey Co., Ill., NE ¼ sec. 13, T. 6 N., R. 12 W., a 20-foot exposure of the Chouteau was studied. The Chouteau is overlain unconformably by approximately 15 feet of massive crinoidal dolomitic limestone similar to that called Sedalia by Moore at Frenchman's Bluff, six miles northeast of Troy, Lincoln Co., Mo. Overlying this limestone with apparent conformity are approximately 20 feet of red and green Fern Glen shales, and they are overlain by the Burlington limestone.

At an outcrop near Castlewood, Mo., 18 miles southeast of St. Louis, Branson (1944, p. 199) described approximately 50 feet of "Chouteau" with the Fern Glen shales included as a facies near the base of the formation. The lower 10 feet of Branson's "Chouteau" is lithologically similar to the Sedalia as defined by Moore (1928, p. 33). Overlying conformably are the red and green Fern Glen shales which grade upward into the Burlington limestone. The Chouteau is absent, and a marked unconformity exists between the Sedalia and the underlying Bushberg formation.

The outcrops of Chouteau in Calhoun and Jersey counties of Illinois and in nearby Missouri show a decided thinning to the north.

Lithology

Bedding and texture.—In outcrops in Illinois the Chouteau formation is composed of irregular beds of limestone which normally range from a few inches to slightly less than a foot thick. Dark gray or black chert nodules form continuous bands 3 to 6 inches thick or disconnected lenticular masses. Geodes 1 to 8 inches in diameter and filled with calcite occur at various intervals. The texture of the Chouteau ranges from sublithographic to very fine-grained with scattered coarse crinoid fragments. Where this formation is a dolomite or dolomitic limestone, the fossils are generally absent and the texture is very fine-grained and saccharoidal rather than sublithographic.

Color.—The Chouteau formation

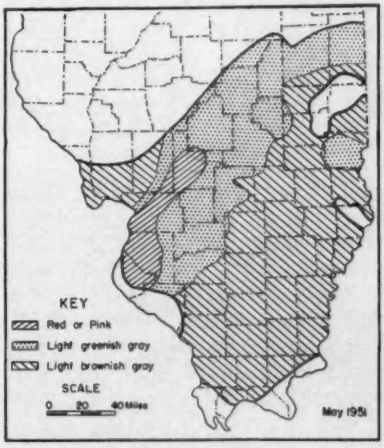

Fig. 1.—Distinctive colors of the Chouteau limestone.

is generally light brownish gray throughout southeastern Illinois and in the outcrop area of Jersey and Calhoun counties of western Illinois (fig. 1). In Wayne and Hamilton counties, the deepest part of the present Illinois basin, the limestone is dark brown. Between the areas of brownish limestone the Chouteau section is normally light greenish gray. In a narrow strip extending northeastward from the Ozark region, well cuttings show part or all of the Chouteau section to be red or

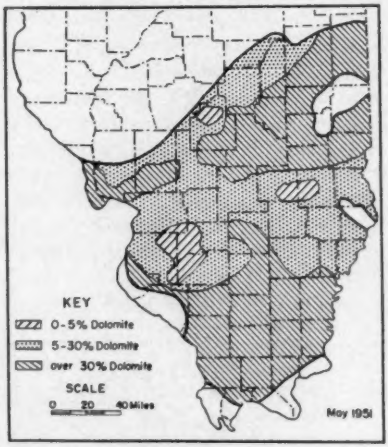

FIG. 2.—Dolomite content of the Chouteau limestone.

pink. The colors are primarily in the groundmass, although some of the crinoid stems also display the red and green tints. Locally some beds of the Chouteau are nearly white. The dolomitic layers become rusty brown when exposed to weathering, while the dense limestone retains its original grayish-brown color.

Dolomite.—The Chouteau formation contains some dolomite almost throughout it (fig. 2). Where observed in outcrops, the dolomite is concentrated in layers seldom over a few inches thick. Silt-size dolomite crystals, however, are present throughout the dense limestone and are occasionally found in the chert nodules. Fossils are not abundant in the dolomitic layers.

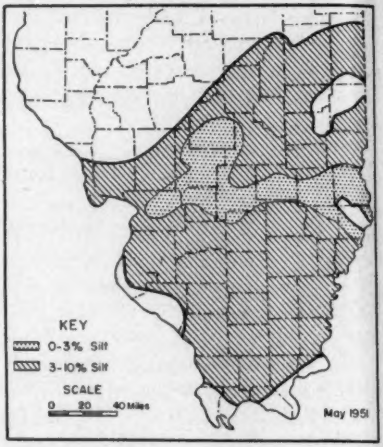

FIG. 3.—Silt content of the Chouteau limestone.

Silt.—In Illinois the insoluble silt content of the Chouteau limestone has remarkably even distribution (fig. 3). Although silt-size particles are present nearly everywhere in the formation, they are not known to exceed 10 percent. Insoluble residues of outcrop samples indicate an increase of silt toward the base of the Chouteau.

Chert nodules.—Chert in the Chouteau coincides with the thickest deposits of the formation. The limestone sections in Illinois and Missouri which contain nodular chert vary in thickness from 30 to 100 feet. Throughout most of Illinois, where the average thickness is 20 feet, no chert has been found.

FIG. 4.—Geologic cross section of the Chouteau limestone across Illinois.

The chert is nodular, black to gray and flinty. It encloses dolomite crystals and numerous small fossils. Normally the nodules comprise continuous bands from 3 to 6 inches thick. The chert zones are several feet apart and tend to be more abundant at the base of the sections. As the Chouteau thins northward in Illinois, the chert loses its zoned characteristics and finally disappears.

Electrical and radioactive characteristics.—The normal position of the Chouteau limestone below the shaly siltstones of the Osage group and above the silty shales of the Kinderhook group causes its electrical character to be quite distinct (figs. 4, 5). On electric logs the thin Chouteau formation generally appears with a moderate to extreme increase in resistivity while the spontaneous potential becomes slightly more negative. Radioactivity logs record the same type of curve as do the electric logs. The neutron radiation curve increases to the right when the limestone is reached; at the same time the gamma radiation curve decreases to the left. This causes a fairly symmetrical deviation away from the center by both lines.

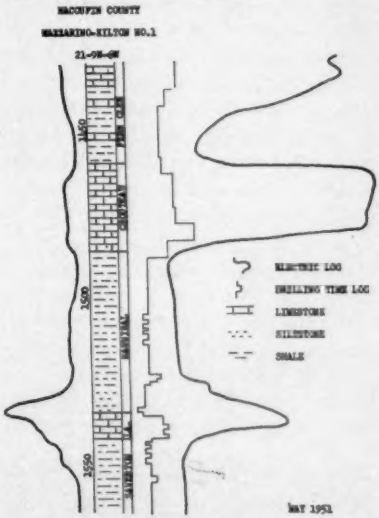

FIG. 5.—Relationship of Chouteau and Louisiana limestones.

STRATIGRAPHIC RELATIONS AND CORRELATION

The Chouteau limestone normally overlies the Hannibal formation with apparent conformity, but in some areas in southwestern Illinois and eastern Missouri it overlaps the Hannibal and lies with unconformity on

the Grassy Creek shale or some member of the Devonian, Silurian, or Ordovician systems. The Chouteau is overlain by several formations of the Osage group. In central and eastern Illinois the Carper sand or the glauconitic Osage siltstone overlies the Chouteau. In western Illinois the massive Burlington limestone takes the place of the siltstone, while in southwestern Illinois the Sedalia and Fern Glen formations overlie the Chouteau. An unconformity at the top of the Chouteau, between the Chouteau and Sedalia formations, was observed near Chautauqua (figs. 6 and 7).

The Chouteau is the uppermost formation of the Kinderhook group of early Mississippian age in Illinois. It is equivalent or approximately equivalent to the *Schellwienella* limestone of Iowa and the lower part of the Waverly formation of Ohio.

Some geologists consider the Chouteau to be equivalent to the Louisiana limestone. The Louisiana limestone, which has limited distribution in Illinois, is separated stratigraphically from the Chouteau formation by the Hannibal shales. Although the Chouteau and Louisiana are not known to occur in the same outcrop, they are both present in several wells in western Illinois, one of which is the well illustrated in figure 5. In southern Calhoun County, subsurface records show that the Hannibal shales pinch out and the Chouteau directly overlies the Louisiana limestone. The Louisiana differs from the Chouteau by being less silty, less cherty, denser, and less fossiliferous. Most of the fossils of the Louisiana are in shaly beds at the base of the formation.

Fig. 6.—Close-up of Chouteau-Sedalia contact at Chautauqua.

Fig. 7.—Chouteau limestone overlying Hannibal shale at Jerseyville Hollow, Jersey Co., sec. 10, T. 6 N., R. 12 W.

The Rockford formation of Indiana is equivalent to the Chouteau limestone. Since the formation is much thicker and better exposed in western Illinois and Missouri than in Indiana, the long-established name Chouteau is accepted. Although Chouteau is the older name, the name Rockford was the first given to the formational unit as now recognized.

Thickness and Distribution

The isopachous map (fig. 8) of the Chouteau limestone was prepared both from well records and outcrop data. The maximum thickness of the Chouteau in Illinois is 74 feet in southern Calhoun County. Normally the formation ranges from 10 to 30

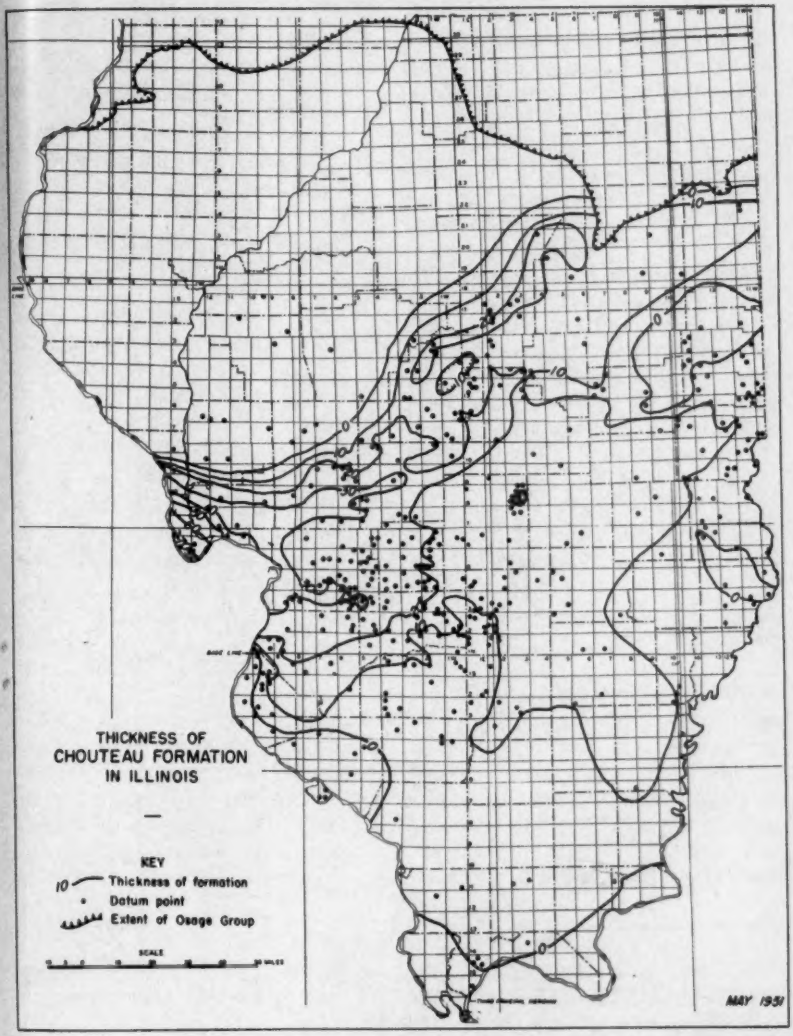

FIG. 8.

feet in Illinois and has an average thickness of approximately 20 feet.

The isopachous map shows no decided thinning of the Chouteau at the crest of the LaSalle anticline, and it does not indicate any thickening of the formation in the Illinois Basin. At the edge of the Ozark region of southwestern Illinois the Chouteau is thin or absent.

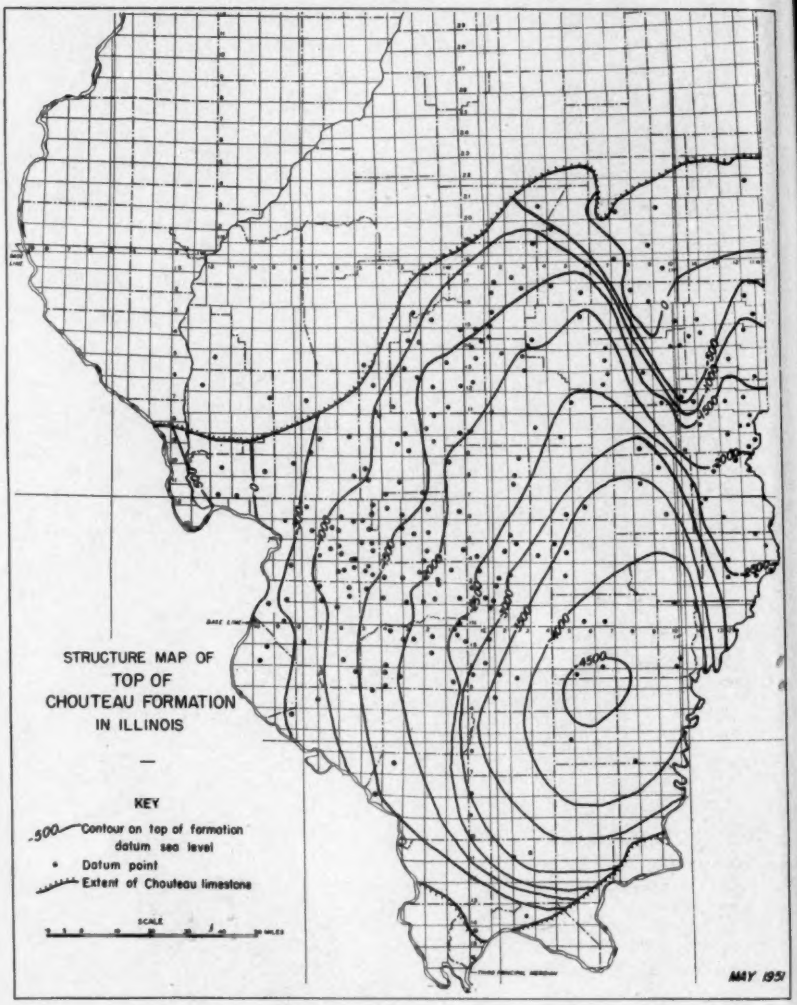

FIG. 9.

Some proved Silurian reef areas are represented on the isopachous map by a thinning of the Chouteau formation, especially in Madison Co., T. 3 N., R. 6 W., and T. 4 N., R. 6 W.; Fayette Co., T. 8 N., R. 3 E.; and in Clark Co., T. 11 N., R. 10 W.

Post-Mississippian — pre-Pennsylvanian erosion had little effect on the distribution of the Chouteau limestone except at its northeastern boundary in northern Champaign and Vermilion counties. There the isopachs are cut by the line rep-

resenting the northerly limit of the Osage group, indicating that erosion cut through the Osage strata and removed the Chouteau.

Structure

A structure map of the Chouteau limestone (fig. 9) shows the maximum difference in elevation of the top of the Chouteau to be over 5000 feet. The highest occurrence in Illinois is in the outcrop area where the Chouteau is 600 feet above sea level, and the lowest is in the center of the Illinois Basin in Wayne and Hamilton counties, where it is 4500 feet below sea level. The closely spaced contour lines near the eastern edge of the state show the steep western limb of the LaSalle anticline.

Environmental Conditions

The irregular bedding of the Chouteau limestone is probably a result of disturbance of the calcareous muds by currents. Free circulation in the sea is indicated by the even distribution of silt.

The dolomite of this formation is believed to be primary or diagenetic because it is widespread and tends to be concentrated in layers. The scarcity of fossils in the dolomitic layers suggests that there was a change in salinity unfavorable to normal marine animals.

Bands of nodular chert, which are parallel to the beds of limestone, appear to represent a distinct environmental condition during the deposition of the Chouteau formation and not a secondary deposit after lithification. The chert was precipitated in a local area of downward warping near the Ozark uplift, from which silt and silica could be contributed to the basin. The chert is generally in the thicker portion of the formation in Missouri and Iowa and is absent from the thinner portion of the formation in Illinois.

The tongue of red limestone extending from the Ozark region suggests that this positive area furnished clastics rich in iron into an oxidizing environment. The greenish limestone surrounding the reddish limestone probably outlines an area in which the environmental conditions were favorable for the biological reduction of ferric iron to ferrous iron.

The boundary between the Chouteau and the overlying Osage formations is distinct, but there is only local evidence of an unconformity. The extensiveness and regularity in thickness of the Chouteau limestone indicate that any erosional interval following deposition of the Chouteau was of minor importance.

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THOMAS HARIOT'S OBSERVATIONS ON AMERICAN GEOLOGY IN 1588

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Thomas Hariot's "A Briefe and True Report on the New Found Land of Virginia" of 1588 is sometimes regarded as the earliest publication on the natural history of what is now the United States (Meisel, 1929, vol. 3, p. 329; Goode, 1901, p. 363). Biologists have heard of his accurate and lively observations on plants and animals, but historians of American geology do not record his considerable and respectable geologic observations.

Observations of topography and mineral resources were made in the first half of the sixteenth century by the French in Canada and by the Spanish in Central and South America (Hornberger, 1937). English observations on minerals, especially of Newfoundland (Rickard, 1932, p. 3), were made before Hariot and were known to him; but to Thomas Hariot must go the credit for first writing in a widely available book form about mineral resources and about geological observations in what is now the United States.

Thomas Hariot (1560-1621) was born in Oxford. He graduated B.A. in 1580 and later became a fellow of Trinity College. Soon after attaining his degree he became mathematical tutor and adviser to Sir Walter Raleigh. Raleigh was long his patron, as was also Henry Percy, Earl of Northumberland, who provided him with a very adequate pension and a house suitable for a gentleman and scholar. Hariot spent most of his life in mathematical and astronomical studies. He is credited with independently inventing the telescope (he appears to have had some such device in Virginia in 1585), with modernizing algebra, and with inventing the signs for inequality. Details on his life are given by Goode (1901), Stevens (1900), Lorant (1946) and Dictionary of National Biography.

Hariot accompanied the Raleigh expedition of 1585 to Virginia[1] as historian, scientist, and adviser. Upon the return of the colonists to England in 1586 he prepared a report which was published in 1588. "A Briefe and True Report of the New Found Land of Virginia" is one of the rarest and most desirable items of Americana, there being but 5 known copies in the world, of which two are in the United States (Adams 1931, p. viii). De Bry republished it in Latin, French, German, and English in 1590, with engravings of water colors made by John White (Sabin, 1870, v. 3, p. 20). Facsimile reprints have been published, and recently it has appeared in an edition with modernized spelling and grammar and with the De Bry illustrations (Lorant, 1946).

[1] The settlement was in the present state of North Carolina on Roanoke Island. The inland explorations were mainly in Albemarle Sound and the Roanoke River. In Hariot's time "Virginia" was the indefinite region north of Florida.

Hariot's well-organized, straightforward, and compact report presents a favorable summary of the new country, its people, its natural history and its resources. He is contemptous of those who issued "malicious, and slanderous reports" and dwelt on the hardships and discomforts they had suffered, dealing with them as follows (Hariot, 1588, p. A4 verso):

> The cause of their ignorance was, in that they were of that many that were neuer out of the Iland where wee were seated, or not farre, or at the leastwise in few places els, during the time of our aboade in the countrey; or of that many that after golde and siluer was not so soone found, as it was by them looked for, had little or no care of any other thing but to pamper their bellies; or of that many which had little vnderstanding, lesse discretion, and more tongue then was needfull or requisite.
>
> Some also were of a nice bringing vp, only in cities or townes, or such as neuer (as I may say) had seene the world before. Because there were not to bee found any English cities, nor such faire houses, nor at their owne wish any of their olde accustomed daintie food, nor any soft beds of downe or fethers; the countrey was to them miserable, & their reports thereof according.
>
> Because my purpose was but in briefe to open the cause of the varietie of such speeches; the particularities of them, and of many enuious, malicious, and slaunderous reports and deuises els, by our owne countrey men besides; as trifles that are not worthy of wise men to bee thought vpon, I meane not to trouble you withall: but will passe to the commodities, the substance of that which I haue to make relation of vnto you.

In his list of "Marchantable commodities" Hariot mentions several minerals, including alum, of which he says (p. B2):

> *Allum*: There is a veine of earth along the sea coast for the space of fourtie or fiftie miles, whereof by the iudgement of some that haue made triall heere in England, is made good *Allum*, of that kinde which is called *Roche Allum*. The richnesse of such a commoditie is so well knowne that I neede not to saye any thing thereof. The same earth doth also yeelde *White Copresse*, *Nitrum*, and *Alumen plumeum*, but nothing so plentifully as the common *Allum;* which be also of price and profitable.

Hariot noted the occurrence of iron and copper. His observations are confirmed in the report of the governor, Ralph Lane (Hakluyt, v. 8, p. 332), which will be quoted later. This passage is of great importance because of the mention of a "minerall man," upon whom we shall remark again. Hariot wrote (p. B3) as follows:

> *Iron*: In two places of the countrey specially, one about fourescore and the other sixe score miles from the Fort or place where wee dwelt: wee founde neere the water side the ground to be rockie, which by the triall of a minerall man, was founde to holde yron richly. It is founde in manie places of the countrey else. I knowe nothing to the contrarie, but that it maie bee allowed for a good marchantable commoditie, considering there the small charge for the labour and feeding of men: the infinite store of wood: the want of wood and deerenesse thereof in England: & the necessity of ballasting of shippes.
>
> *Copper*: A hundred and fiftie miles into the maine in two townes wee founde with the inhabitaunts diuerse small plates of copper, that had beene made as wee vnderstood, by the inhabitantes that dwell farther into the countrey: where as they say are mountaines and Riuers that yeelde also whyte graynes of Mettall, which is to bee deemed *Siluer*. For confirmation whereof at the time of our first arriuall in the Countrey, I sawe with some others with mee, two small peeces of siluer grosly beaten about the weight of a Testrone [testone, shilling], hangyng in the eares of a *Wiroans* or *chiefe Lorde* that dwelt about fourescore myles from vs; of whom thorowe enquiry, by the number of dayes and the way, I learned that it had come to his handes from the same place or neere, where I after vnderstood the copper was made and the white graynes of mettall founde. The aforesaide copper wee also founde by triall to holde siluer.

In addition to the first section on merchantable commodities Hariot included a second section on "commodities for victuall and sustenance," which includes no minerals, and a third section on "things as is behoofull for those which shall plant settle and inhabit to know of . . . for building and other necessary uses." After discussing timber for houses and ships he says (p. D4 verso, E1):

Now for Stone, Bricke and Lime, thus it is. Neere vnto the Sea coast where wee dwelt, there are no kinde of stones to bee found (except a fewe small pebbles about foure miles off) but such as haue bene brought from farther out of the maine. In some of our voiages wee haue seene diuers hard raggie stones, great pebbles, and a kinde of grey stone like vnto marble, of which the inhabitants make their hatchets to cleeue wood. Vpon inquirie wee heard that a little further vp into the Countrey were of all sortes verie many, although of Quarries they are ignorant, neither haue they vse of any store whereupon they should haue occasion to seeke any. For if euerie housholde baue [have] one or two to cracke Nuttes, grinde shelles, whet copper, and sometimes other stones for hatchets, they haue enough: neither vse they any digging, but onely for graues about three foote deepe: and therefore no maruaile that they know neither Quarries, nor lime stones, which both may bee in places neerer than they wot of.

In the meane time vntill there bee discouerie of sufficient store [stone?] in some place or other conuenient, the want of you which are and shalbe the planters therein may be as well supplied by Bricke: for the making whereof in diuers places of the countrey there is clay both excellent good, and plentie; and also by lime made of Oister shels, and of others burnt, after the maner as they vse in the Iles of Tenet and Shepy, and also in diuers other places of England: Which kinde of lime is well knowne to bee as good as any other. And of Oister shels there is plentie enough: for besides diuers other particular places where are abundance, there is one shallowe sounde along the coast, where for the space of many miles together in length, and two or three miles in breadth, the grounde is nothing els beeing but halfe a foote or a foote vnder water for the most part.

This much I can say further more of stones, that about 120. miles from our fort neere the water in the side of a hill was founde by a Gentleman of our company, a great veine of hard ragge stones, which I thought good to remember vnto you.

The description of Hariot and the independent narrative of Lane show that part of the colonists crossed the Coastal Plain to the Fall Line and entered the Piedmont. In his "Conclusion" Hariot gives the first description of the changing character of the Coastal Plain toward the Piedmont. Americans would now say that an affirmative answer has been given to his optimistic final question (p. F2 verso, F3):

Now I haue as I hope made relation not of so fewe and smal things but that the countrey of men that are indifferent & wel disposed maie be sufficiently liked: If there were no more knowen then I haue mentioned, which doubtlesse and in great reason is nothing to that which remaineth to bee discouered, neither the soile, nor commodities. As we haue reason so to gather by the difference we found in our trauails; for although all which I haue before spoken of, haue bin discouered & experimented not far from the sea coast where was our abode & most of our trauailing: yet somtimes as we made our iourneies farther into the maine and countrey; we found the soyle to bee fatter; the trees greater and to growe thinner; the grounde more firme and deeper mould; more and larger champions [fields]; finer grasse and as good as euer we saw any in England; in some places rockie and farre more high and hillie ground; more plentie of their fruites; more abundance of beastes; the more inhabited with people, and of greater pollicie & larger dominions, with greater townes and houses.

Why may wee not then looke for in good hope from the inner parts of more and greater plentie, as well of other things, as of those which wee haue alreadie discouered?

Ralph Lane, governor of the colony left in Virginia over the winter

of 1585-86, gives more details about the journey on which the iron and copper were found. The journey appears to have been made primarily to search for a reported copper mine, which was presumably the source of the copper plates possessed by the local Indians. He did not find the mine. In making his excuses to Raleigh it is evident that importance of the discovery of metals was well recognized. It is in this passage that we find a clue to the identity of Hariot's "minerall man" (Hakluyt, v. 8, p. 331-332; modernized in Lorant, p. 741, 742):

> I have set downe this Voyage somewhat particularly, to the ende it may appeare unto you (as true it is) that there wanted no great good will from the most to the least amongst us, to have perfited this discoverie of the Mine: for that the discovery of a good Mine, by the goodnesse of God, or a passage to the Southsea, or some way to it, and nothing els can bring this Countrey in request to be inhabited by our nation. And with the discovery of either of the two above shewed, it will bee the most sweete and healthfullest climate, and therewithall the most fertile soyle (being manured) in the world: . . .
>
> For this river of Moratico promiseth great things, and by the opinion of M. Hariots the head of it by the description of the Countrey, either riseth from the bay of Mexico, or els from very neere unto the same, that openeth out into the South sea.
>
> And touching the Minerall, thus doeth M. Youghan affirme, that though it be but copper, seeing the Savages are able to melt it, it is one of the richest Minerals in the world.

This Master "Youghan" is undoubtedly the "minerall man" of Hariot (1588, p. B3). But no Youghan appears in the list "of those as well Gentlemen as others, that remained one whole yeere in Virginia, under the Government of Master Ralph Lane" as given in Hakluyt (v. 8, p. 317-318). "Captaine Vaughan" is listed eighth in the list of 107 men. It is logical to assume that "Youghan" is a printer's error for "Vaughan." If so, who was "Captaine Vaughan"? He is the only man listed as "Captaine." Fourteen are listed as "Master," including Hariot, but in the text several are referred to as "Captaine" (p. 316).

The late sixteenth century "mineral man" appears to have been a combination geologist, mining engineer, assayer, and refiner. The profession was recognized and the title not uncommon (Hoover and Hoover, 1912, footnote, p. 283). Master Vaughan appears to have been the earliest English one in what is now the United States, but he was not the earliest attached to an English expedition to North America. That honor goes to "the minerall man and refiner . . . Saxon borne, honest and religious, named Daniel," who is reported by Edward Hayes to have been attached to the expedition of 1583 of Sir Humphrey Gilbert to Newfoundland and neighboring regions (Hakluyt, v. 8, p. 60). Along with Sir Humphrey, both Daniel and his ore specimens were lost on the return to England (*ibid.*, p. 67, 71).

It is possible that Hariot knew more than one mineral man. His patron, Raleigh, was a Devonshire man, who is reputed to have been a favorite of the miners of Devon and Cornwall. Raleigh became Warden of the Stannaries in 1585 and was active in using his new powers over the mining districts he already knew so well (Encycl. Brit., article Raleigh).

It is easy to speculate that after Hariot's return to Eng-

land in 1586 he came into contact with the mine captains, mineral men, and refiners of Cornwall. Perhaps Captain Vaughan himself was a Cornish mining man. In the two and one-half years between his return and the publication of "Briefe and True Report," Hariot may have had many opportunities to increase his knowledge of mineral resources. But at any rate we can be impressed by his geological knowledge when we summarize what Hariot knew, from personal observation and actual experiment, about the geology of Virginia:

1. There was a wide flat coastal region (Coastal Plain) without prominent stones.

2. Along a distinct line (Fall Line) hard (crystalline) rocks appeared and continued an unknown distance into the country (the Piedmont).

3. The character of the crystalline rock varied and included a "hard ragge stone" (see "rag," Fay, p. 554; Rice, p. 336).

4. The rocky ground at places contained iron, which he had seen and knew on professional advice to be ore.

5. Copper occurred beyond the limit of exploration, but supposedly not far away. The material was positively copper on the basis of its melting character.

6. The copper was silver-bearing, as determined by trial by Hariot and the "minerall man."

7. Excellent and plentiful clay for brick existed in the Coastal Plain.

8. Probably the fossil shells in the Coastal Plain sediments were recognized as remains of actual organisms. Hariot knew enough about fossils[2] and was interested enough to discuss them in 1589 with Jacob Cole, nephew of the geographer Ortelius (Parks, p. 168, 251). Almost certainly he had made note of them in Virginia only three years before. He had noted the abundance of oyster shells there and it would have been strange if he had not noted similar, but fossil, shells in the Coastal Plain sediments. Certainly other observers who came after him did so and made the proper interpretation (Evans, 1749; also quoted in White, 1951, p. 154).

[2] Until the eighteenth century shells, bones, teeth, crystals, stalactites, and other objects were all called fossils. Much of the early insistence on the inorganic origin of fossils is thus more easily understood.

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PHYSICS

CIRCUITS FOR PHOTOMETRY

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Two instruments that have been used with considerable success for the past few years in the University of Illinois photometry laboratory are here presented as an answer to two rather common and vexing problems of the photometry laboratory. The first problem is that of measuring the currents of barrier layer-type photovoltaic cells. The currents cannot be satisfactorily measured with a galvanometer and ayrton shunt because of the change in circuit resistance as the range is changed. The multirange microammeter recommended here has as one of its features constant resistance on all ranges. The second problem is that of comparing the intensity of light sources. For years the photometer heads used for this purpose have been either of the visual type, such as the Lummer-Brodhun, or extremely complicated photoelectric devices using rotating mirrors and elaborate circuits. The null balance photoelectric photometer head presented here is very simple to construct and use.

A Multirange Microammeter

The usefulness of this instrument is not limited to the field of photometry. It can be used in any laboratory where small d-c currents must be measured. A large part of its usefulness and versatility stems from the fact that it can be quickly assembled from parts to be found in almost any physics laboratory.

An instrument for measuring small d-c voltages that has been used for many years and is still one of the best is the Poggendorff type 2 potentiometer. This potentiometer in the form used for measuring thermocouple voltages is often referred to as a "Lindeck and Rothe element," after the men who developed it for that purpose. This instrument used to measure the voltage drop across a known resistance can, like any potentiometer, be used for the measurement of currents as well as voltages.

Figure 1 shows the circuit of the instrument as used for the measurement of photocell currents. The operation is as follows:

The current I_x produced by the photocell passes through the 100 ohm resistor R causing a voltage drop across the resistor. The current through the tapped resistor R_1 is adjusted until the galvanometer indicates that the voltage drops across the two resistors are equal. The current I_1 is then read on the milliammeter and I_x is obtained from the relation I_x equals I_1 (R_1/R).

The instrument has for the tapped resistor R_1 a single length of manganin wire with taps soldered to it at suitable points. The final adjustment of this resistor was made by scraping the wire to reduce its cross section while its resistance was being measured with a Kelvin bridge. The circuit as shown has the following features:

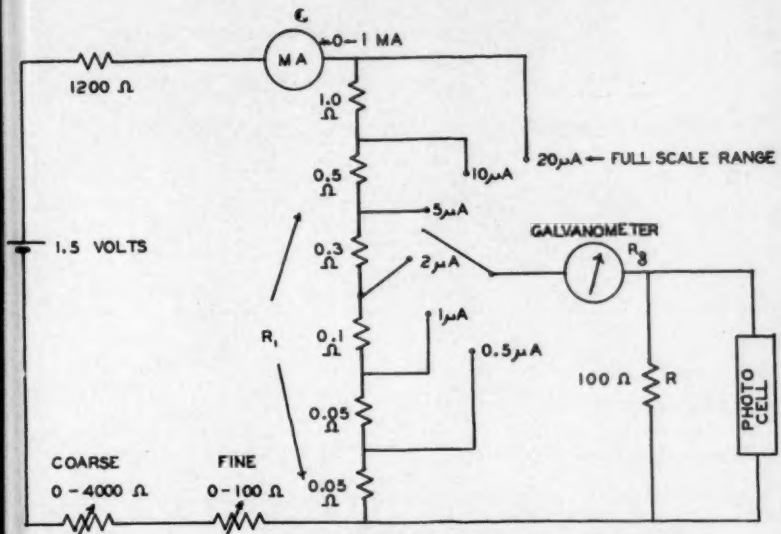

FIG. 1.—Circuit of multirange potentiometer-type microammeter.

1. The instrument is multi-range.

2. The impedance inserted into the measuring circuit is constant for all ranges.

3. The sensitivity (using proper circuit components) is essentially that of the galvanometer used.

4. The galvanometer can be critically damped for all ranges, thus speeding the instrument use.

5. The device is simple to construct from parts that can be easily obtained in most laboratories.

6. The potentiometer-type microammeter (fig. 1) has the further limitation that readings cannot be taken on the lower third of the scale. The use is thus limited to the more accurate portion of the scale.

7. The basic accuracy of the instrument is dependent on the accuracy of the milliammeter and the resistors used for R and R_1. Assuming adequate galvanometer sensitivity and 0.1 percent resistors used with a milliammeter that is accurate to 0.5 percent of full scale, a full-scale accuracy of 0.7 percent and an accuracy at ⅓ of scale of 1.7 percent is obtained.

8. The device is extremely stable. The calibration of the instrument will hold for long periods of time since it is primarily dependent on the stability of R and R_1 and on the stability of the indicating instrument.

Analyzing the circuit to determine its sensitivity gives the following result: If the current being measured changes from the value for which the circuit is balanced by an amount ΔI_x then the galvanometer current I_g is equal to $I_x/(1 + R_g/R)$, where R is the resistor through which the current I_x passes and R_g is the resistance of the galvanometer. From this analysis it is evident that as R becomes large in comparison to R_g then I_g is approximately equal to I_x. For this condition of R large in comparison to R_g, the change in the

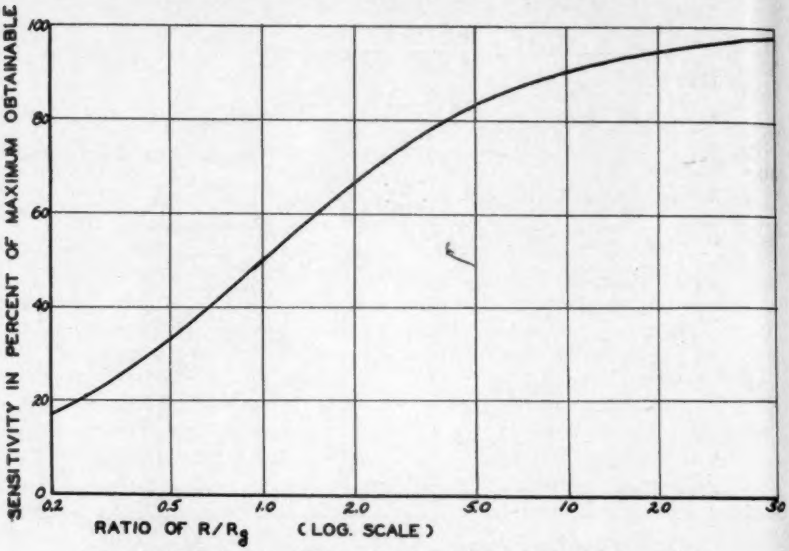

FIG. 2.—Relative sensitivity of potentiometer-type microammeter.

unknown current that can be observed approaches the minimum detectable galvanometer current. The effect of the ratio of R to R_g on the sensitivity is indicated by figure 2. The curve shows that for values of R exceeding four times R_g the sensitivity is quite comparable to the maximum sensitivity obtainable. From figure 2 and the following rules a circuit can be designed to meet almost any requirement:

1. R should be small so that it will not alter the current which is being measured. For photocell currents R should not exceed 300 ohms.

2. For maximum sensitivity the galvanometer resistance should be small compared to R.

3. The current sensitivity of the galvanometer should be such that the minimum observable deflection is less than 1/250th of the I_x range desired.

A NULL TYPE PHOTOELECTRIC PHOTOMETER

An ever-present problem of a photometry laboratory is comparing the intensity of two sources. The usual equipment for this procedure is a bar photometer plus some type of optical photometer head such as the Lummer-Brodhun. Experienced observers using such equipment usually can reproduce their results within one percent. However, owing to differences in vision and judgment, it is often noted that two individuals, while consistent in reproducing their own results, will get results that differ by several percent. Often the sources to be compared do not have the same color, so the spectral response of the observer adds another unknown to increase the uncertainty of such measurements.

In the University of Illinois photometry laboratory the special photo-

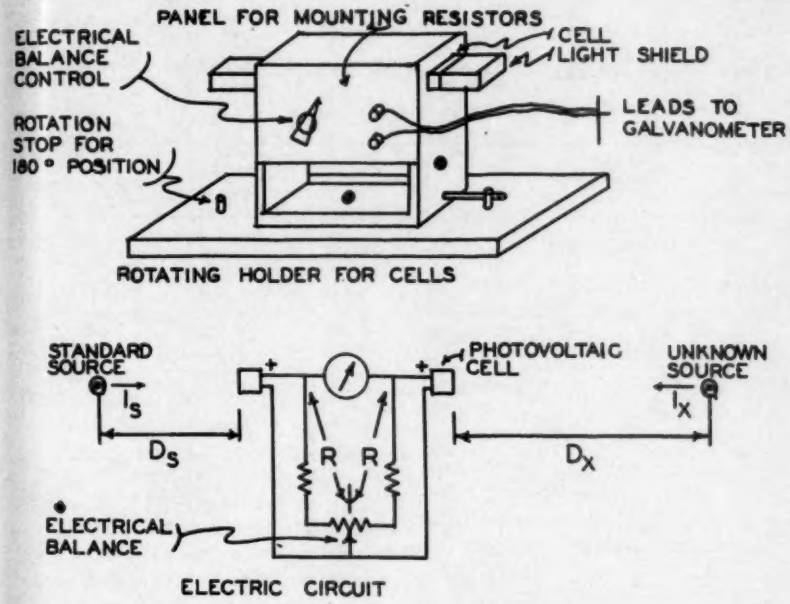

FIG. 3.—Photoelectric photometer head.

meter head and circuit (fig. 3) have been used with considerable success. This device uses a pair of selenium photovoltaic cells with filters which make their spectral response approximately that of the standard observer. An increase in sensitivity can be obtained when comparing similar sources if unfiltered cells are used.

The problem of comparing two sources using two cells is that even though the cells are purchased as "matched" they usually do not agree by better than 1 or 2 percent. The potentiometer rheostat adjustment of the circuit shown eliminates this problem. By adjusting the moving contact to the proper point the circuit is compensated for inequality of the cells. The balance procedure is as follows:

1. The two lamps are mounted on the bar with the head between them. The distance from lamp to cell is altered to obtain approximately zero galvanometer current.

2. The head is rotated 180 degrees so each cell now looks at the other lamp. The galvanometer will probably deflect because the cells are still unmatched. The galvanometer is then moved toward zero by moving the contact of the potentiometer.

3. The head is again rotated and the distance adjusted.

4. The procedure of alternately adjusting the distance and the cell match is repeated until the galvanometer reads zero when the photometer head is rotated. The cell-to-lamp distances are then determined and the intensities computed.

This circuit is sufficiently sensitive so that the control of the lamp volt-

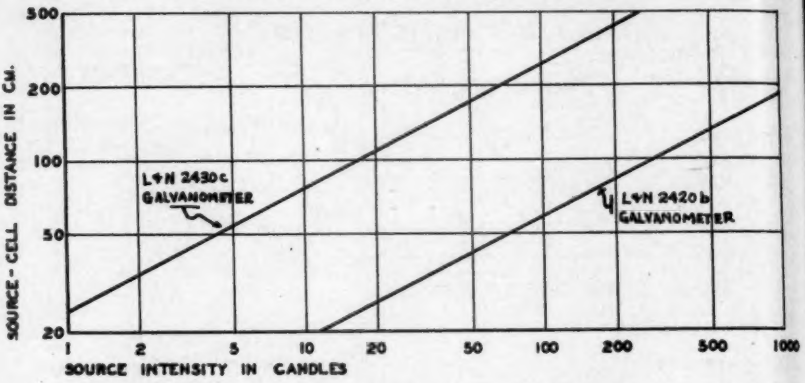

FIG. 4.—Sensitivity of photoelectric photometer.

Assumed Conditions

Galvanometer	L&N 2420b	L&N 2430c
Minimum observable current	0.01 microampere	0.0007 microampere
Galvanometer resistance	25 ohms	25 ohms
CDRX	80 ohms	350 ohms
R (See figure 3)	40 ohms	175 ohms
Photocell sensitivity	0.5 microamp./Ft-C	0.5 microamp./Ft-C
Sensitivity to distance	1 part per 1000	1 part per 1000

ages becomes a major problem. If the circuit is used with incandescent lamps, and the sensitivity is such that distance changes of 1 part in 1000 can be detected, the lamp voltages must be known and controlled to 1 part in 4000 in order to justify the sensitivity.

In this circuit, since much manipulation is needed to achieve balance, speed of galvanometer response is important. It will be best to make R equal to one half the CDRX of the galvanometer so, the galvanometer will be critically damped.

If a galvanometer whose constants are known is used and its minimum detectable change in current is determined, the value of cell current corresponding to this galvanometer current can be computed. This cell-current value can be used to obtain the cell illumination required to produce such a current, which in turn serves as a basis for computing the intensity at any assumed distance. This process has been done for two galvanometers, and the resulting curves are shown in figure 4. This curve shows that with a moderately high sensitivity galvanometer the circuit will operate satisfactorily even with weak sources.

One note is needed on the balance procedure. The balance procedure roughly resembles that for an a-c bridge having a slow convergence. Therefore considerable technique is needed in order to achieve balances in a minimum amount of time. This technique can come only with practice.

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TWO SIMPLE PHOTOMETRIC TECHNIQUES

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For many years, training in physics has been plagued by the fact that there is more material for the student to learn than there is time in which he may learn it. In recent years, too, the increasing commercial importance of atomic and nuclear physics has greatly increased the time allotted to their study, even in undergraduate courses.

That branch of physics called optics, although one of the oldest, is —with its close relative, photometry —still one of the most active. New developments appear every year or so, and a multitude of commercial applications are in use, with more appearing every day. As an attempt to provide more useful material, both on fundamental optical laws and on their applications in commerce and industry, two techniques are here described.

The law describing specular reflection is familiar to every student of physics; those laws describing diffuse reflection are much less so. Work in illumination and in photometry is based more upon diffuse than upon specular reflection. Measurements of specular and of diffuse reflection coefficients, made with ordinary and polarized light, can disclose many of the characteristics of materials—whether they are metallic or dielectric, their surface condition, as well as color, texture, and gloss. The simple equipment for such measurements may also be used to demonstrate many fundamental optical laws.

Definitions

The coefficient of specular reflection is usually defined as the ratio of the reflected intensity to the intensity of the incident light, whereas diffuse reflecting power is usually defined as the ratio of the entire reflected luminous flux to the incident flux. Consequently, a true measure of diffuse reflecting power requires measurement of all the light reflected over a 180° spherical angle.

Techniques and Equipment

Let us first consider specular and diffuse reflection separately. Figure 1A illustrates the specular reflection of a pencil of light incident at the angle Θ. (The direction of the incident light is indicated by the dotted line, while the solid line represents the intensity of the reflected light plotted in polar coordinates with the point of incidence as origin.) In figure 1B the reflection of a similar pencil of light from a completely diffuse reflector (conforming to Lambert's Law) is shown; and in figure 1C the reflection pattern for a surface having both specular and diffuse reflectivities is drawn. This third condition is most often found in nature; neither perfectly specular reflectors nor perfectly diffuse reflecting surfaces are ordinarily found. (Smooth surfaces of magnes-

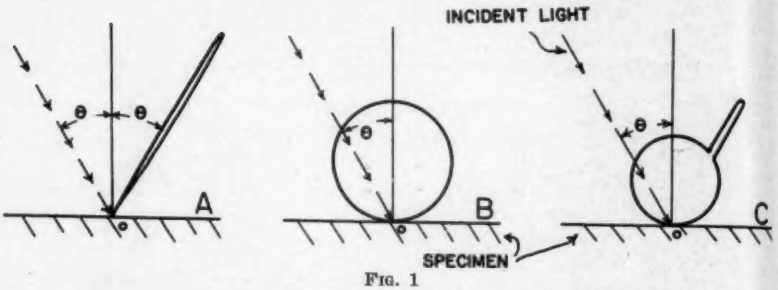

FIG. 1

ium oxide or carbonate, or even of plaster of paris, are often used as standards.) A curve such as that of figure 1C might be from a rather dusty mirror, or from a piece of matte paper coated with varnish.

It should be noted that these curves represent only the intercept on the plane of the incident light, while the actual pattern is a three-dimensional figure of some sort; that for figure 1B would be a sphere.

Figure 2 is a sketch of a simple apparatus by which these polar curves may be taken. It consists of two hinged arms, one carrying a light source with a collimator (which projects a slender pencil of light upon the test surface) and the other carrying a barrier-layer photoelectric cell, by which the intensity of the reflected light may be measured.

Details of construction may vary, but the essential points are these: a well-defined pencil of light must be produced; suitable masks and shields must be provided so that only light reflected from the specimen reaches the photocell; and the two arms should be so hinged that as they are moved the point of incidence at the specimen does not

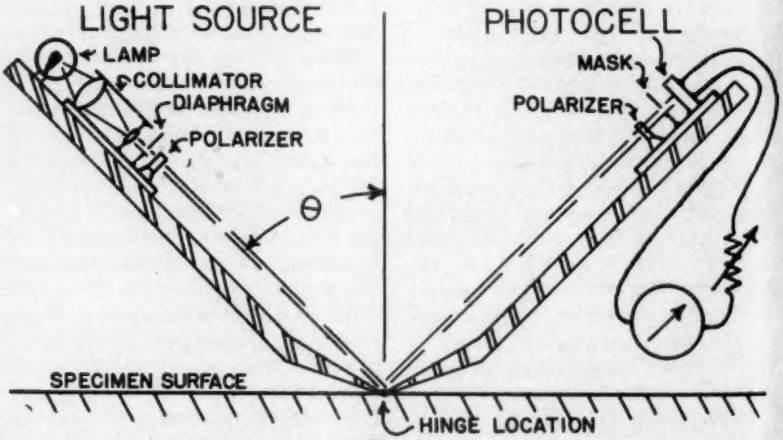

FIG. 2

change. (The hinge axis, therefore, should lie in the plane of the specimen surface, and also should be intersected by the light beam.) An automobile-type bulb will provide enough light to operate the apparatus if a moderate-sensitivity galvanometer is used. An aperture or diaphragm is placed just before the photocell, so that only the specularly reflected pencil of light passes to the cell.

Polarizing devices should be mounted on both collimator and photocell, to act as polarizer and analyzer respectively. Either may be used when measurements are made on dielectric materials, but it is convenient to have both for measurements on metallic surfaces.

In figure 3, the curves for reflected intensity versus reflecting angle are plotted for both metallic and glass surfaces; these curves also demonstrate the differences between well-polished and poorly-polished surfaces. Figures 3A and 3B were prepared by sweeping the incident beam and the light-receiving photocell simultaneously, keeping the angles of incidence and of reflection equal. Both ordinary and polarized light are used, the curve for ordinary light being the solid line, and for polarized light the dotted line. The two materials give curves which differ for these reasons: at normal incidence little light is reflected from the glass surface, much from the metallic surface; at the polarizing angle (about 57° for glass, and 70° to 80° for many metals) there is a decrease in reflected intensity in both instances—for glass the intensity drops to nearly zero while for metals the decrease is only perhaps 30 to 50 percent. These data can be used to explain the application of Snell's Law for both glass and metallic surfaces, there being nearly complete

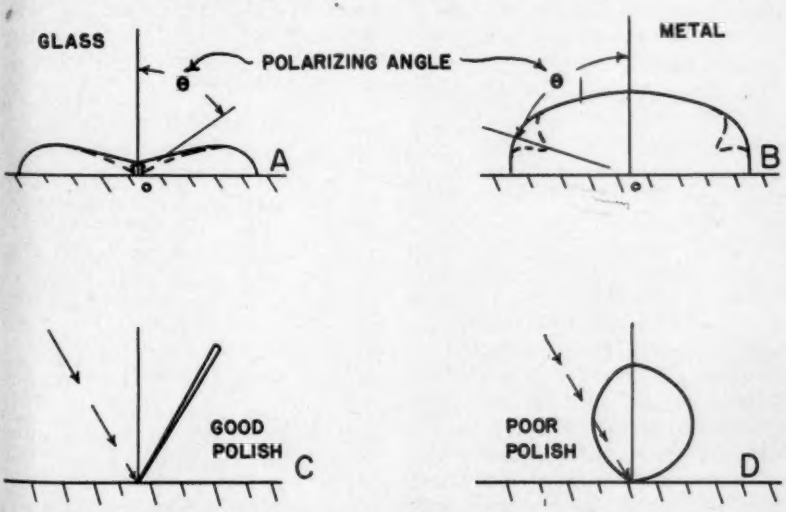

FIG. 3

plane-polarization for glass, while the effect at metallic surfaces is one of elliptic polarization.

The surface characteristics displayed by these data may be of value in identification of materials:

If the polar curve of reflected intensity looks like that of figure 3A, the material is probably a glass (or a plastic of similar optical character), though its color may be anything from transparent to jet black, and it may have any reasonable degree of polish. Its opacity does not obscure the measurement. If the glass is poorly polished, the reflected intensities will be lower than those for a good polish, but the shape of the curve will not change greatly. The drop in intensity at the polarizing angle will be less sharp, but the polarizing angle will still be about 57° for crown glass, and 58° for flint glass.

Conversely, if the shape of the curve remains essentially that of figure 3B, the surface is probably metallic in nature.

In order to determine the degree of polish, a fixed beam of light is used, incident at perhaps 45°, while the arm carrying the photocell is traversed, and the intensity of the diffusely reflected light is plotted at all angles except the incident angle (where the reflection is specular). An optically polished plate produces a pattern like that of figure 3C; a ground-glass surface produces a pattern much like that of figure 3D. This is essentially a measurement of gloss, or of surface smoothness; the gloss, or polish, of surfaces is important both from the technical and the commercial standpoint, though there is little useful information available on the subject and on apparatus for its measurement.

Comparative measurements, of moderate accuracy, may be made easier by providing another mask which is the converse of the one normally placed before the photocell, that is, a mask which intercepts the specular beam while permitting the diffused light to pass. It is then possible to make a reading with the first mask (of intensity of specular reflection) and one with the second mask (of intensity of diffuse reflection over a small solid angle) and to multiply their ratio by a factor determined by experiment, affording a measure of the gloss or polish of the sample. The accuracy of this measurement can never be very high, since it involves measuring only a small portion of the total light flux reflected by the sample. For a really high degree of accuracy, it would be necessary to use some form of integrating sphere to gather all this diffusely reflected light, but for many purposes the simple method described is adequate.

The same optical principles can be applied to another piece of equipment, much more convenient in use but less flexible in ability. It employs a source of collimated light projected through a small aperture in a barrier-layer photocell; the light which is reflected specularly returns along its original path and is lost, while the diffusely reflected light is gathered by an integrating sphere and applied to the photocell. The instrument is standardized by directing it at a standard diffuse reflector (as a magnesium oxide surface) and adjusting the galvanometer circuit until the deflection is

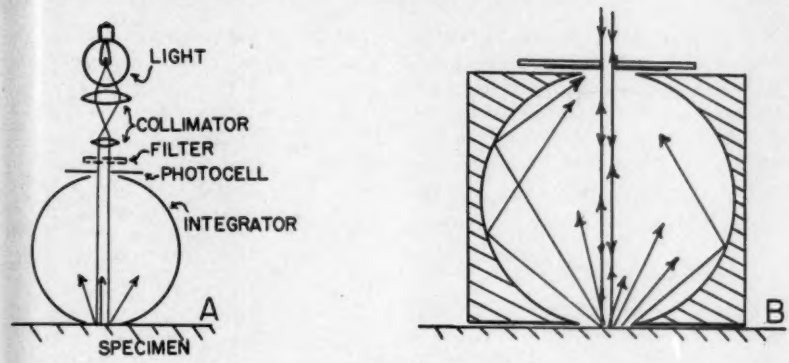

FIG. 4

100 divisions; then the deflection observed when the instrument is directed at an unknown surface indicates the diffuse reflecting power in percentage. Figure 4B shows the optical paths within the instrument in use.* Since light is applied only at normal incidence in this device, no measurements can be made with polarized light. Diffuse reflectivity, as well as color, is easily measured.

This instrument measures diffuse reflection of surfaces as described above, and is at its best when used on surfaces having low specular reflectivity. It can, however, be applied to glass containers to determine the whiteness or the color of the contents of the container; in this application the light reflected specularly from the glass returns through the aperture and is not measured.

Color is measured by introducing primary-color filters before the source of light; then the reflecting power of the specimen is measured for each of the three colors. If the three filters are mounted in a rotating disc, the three measurements may easily be made in a minute or so. For each color, the galvanometer is initially adjusted to 100 divisions, so that the reading is made in percentage.

As described, these instruments are not intended for high accuracy; the ordinary user may achieve perhaps two percent, although the sensitivity would imply higher accuracies. The care in design and construction is an important factor in affording accurate results. Usable data have been taken, however, with equipment employing automobile-type bulbs, inexpensive achromatic lenses as collimators, and pointer-type galvanometers with ½ microampere per division sensitivity. Since the barrier-layer cells operate best into rather high resistances, it has been convenient to employ a series-resistance adjustment. Satisfactory cells have been procured, with outside diameter of about ½ inch, and an aperture of ⅛ inch. The actual design of the integrating spheres has not been difficult; some of nearly cylindrical shape have been used, although a two-inch diameter spherical chamber produced the

* In this connection, I am happy to acknowledge the assistance and cooperation of Antony Doschek, of Doschek Associates, Pittsburgh, Pennsylvania.

best results, with ½-inch apertures at opposite ends for the passage of light. A simple collimator has been made using two achromatic lenses, the first imaging the source at the center of the second lens, and the second imaging the field on the photocell.

Applications

Some applications have already been mentioned; others are obvious. One, of more than usual interest, is the inspection of thin films, such as oxide films on metals.

As a specific instance, aluminum reflectors might be checked for polish during the polishing process. When the desired degree of polish is reached, a lacquer may be applied or the surface anodized to protect against corrosion and soiling. The degree of polish is easily determined by the diffuse reflectivity; the presence or perfection of an anodized or lacquered protective coating may be ascertained by examination by polarized light at the proper angle. The thin oxide film, practically invisible in ordinary light, is conspicuous under polarized light. An added advantage is that the surface is not contaminated during the measurement.

Similarly, glass (or other dielectric) coatings on metals may be inspected. Anomalous polar curves are occasionally found; usually they indicate an unusual surface condition.

The measurement of whiteness of paper, cloth, etc., has been mentioned—this is simply measurement of diffuse reflectivity. Smoothness of metal surfaces, color of pigments, stability of color of bottled products exposed to light, effectiveness of sandblasting on surfaces—these and other attributes may be measured with the two devices described.

The educational functions of the equipment likewise are evident; several optical principles may be demonstrated quickly and easily, and the applications of such methods in science and industry cited as examples, to add interest. The simplest points, such as the laws of reflection, Lambert's Law, and Brewster's Law, may be graphically illustrated; less familiar theory, such as the anomalous polarization effects at metallic surfaces and the resulting elliptic polarization, may be displayed.

REVERSAL OF DIRECTION OF ARC MOVEMENT IN A MAGNETIC FIELD UNDER REDUCED AIR PRESSURE

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Micro Switch, Freeport

It costs not less than $200, and usually more, per pound per year to carry equipment aboard aircraft. For this reason, space economy in electrical circuit-interrupting devices was attempted by use of modern permanent magnets for d-c arc blowout. It has been shown that a magnet of high coercivity and weighing only 1/10 of an ounce can be used in a switch to snuff a 10-ampere arc at ground level with long-lived reliability. Switches so equipped served well until planes began to fly higher than about 20,000 feet. Laboratory tests at simulated higher altitudes, however, revealed unexpected relations between ambient air pressure and the movement of arcs in transverse magnetic fields. Under certain relations of flux density and contact separation, it was observed that:

1. As air pressure decreases the arc moves less and less in the direction predicted by Ampere's law (the familiar left-hand, three-finger rule).

2. Over a range of critical pressure the arc is immobile and may destroy contacts.

3. At pressures below the critical range, the arc moves in the opposite direction to that predicted by Ampere's law.

4. Over a range of small contact separations, and within certain pressure ranges, there is discontinuity in switch-interrupting ability.

5. The higher the flux density the lower the altitude at which immobility occurs.

6. Variation in flux density over the length of the arc affects its movement.

The nature of arc structure and movement is most easily observed when contact separation is wide enough to interrupt the arc under the condition of immobility. For such observation, curved electrodes which can be moved from the closed to the open positions by electromagnetic means are mounted in a bell jar, as shown in figure 1.

Figure 2 shows the nature and position of the arc under specific conditions of flux and current values, at various pressures. Study of the action here seen makes it possible to explain the performance of a switch like that in figure 3 over a range of pressure changes and when adjusted for several contact separations, all of which are less than that which will interrupt the arc without blowout action of the magnet.

Where contacts are separated by 0.020 inch, there is a discontinuity in the arc-snuffing operation of the blowout magnet up to approximately 15,000 feet of altitude. With 0.035-inch contact separation discontinuity does not begin until approximately 10,000 feet of altitude, and continues to approximately 20,000 feet of altitude. The switch with contact separation of 0.070-inch was

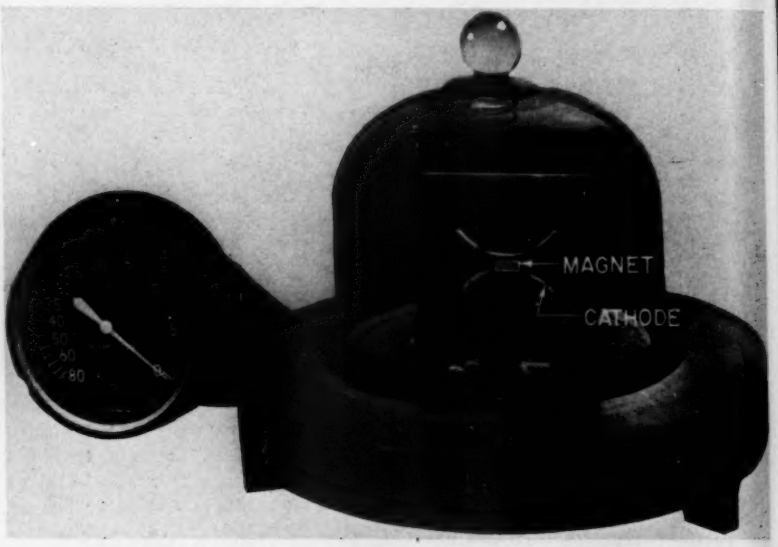


FIG. 1.—Silver arcing horns, solenoid driven for closing and opening contact. Permanent magnet provides a total of 550 lines of force. (Data supplied by Dallas.)

successfully used in many relatively low-flying aircraft. Here there is no discontinuity, but the switch failed to interrupt more than 1¾ amperes above about 20,000 feet of altitude.

From these data it might be reasoned that the difficulty of switching at altitude can be avoided by use of wide-contact separation. This is not always possible in the case of relays and sensitive switches, for operation force, motion, and switch size are limited by aircraft design.

When the unexpected effects of altitude were first observed in the Micro Switch laboratories in 1942, eminent authorities were consulted for explanation of the phenomena and for practical help in the design of switches which would avoid the problems. No one was found who was aware of the effect, and the only reference discovered in the literature is in Faraday's Diary,[1] and that barely hints at one phase. Following Micro's observation, a number of articles have been published in which there is agreement that the mechanism of the effect is to be sought in the cathode spot. The appearance of the arc shown in figure 2 bears out this reasoning, for the retrograde movement of the cathode end always leads the main column.

Dr. Charles G. Smith has reported the reverse motion of the cathode spot in mercury arcs, and suggested that it may be due to the negative Righi-Leduc effect.[2, 3] His work, however, appears to have been done entirely on mercury arcs at about 2-

[1] Michael Faraday's Diary, Jan. 13, 1862, vol. VII, 1820-1862.

[2] Heat is pushed at right angles to the magnetic field and at right angles to the temperature gradient.

[3] Smith, Charles G., The mercury arc cathode: Phys. Rev. 62: 48, July 1942.

FIG. 2.—Position assumed by a 4.5 ampere 30 volt d-c arc between silver electrodes separated 0.200 inch at the center in the field of a permanent magnet providing a total of 550 lines, under varying simulated altitudes. The lower electrode was the cathode. The load circuit had an L/R time constant of approximately 0.035 second. (Data supplied by Dallas.)

millimeter pressure. Other workers have found retrograde movement between electrodes which produce both positive and negative Righi-Leduc effects (for example, Fe and Mg, Cu and Ag).[6] It seems improbable that changes of pressure could slowly reduce and then alter the sign of the Righi-Leduc effect. Yamamura points out that the conditions producing immobility, and its range, vary with electrode materials.[4-7] Various investigators of conditions in the cathode spot estimate that current density may be as great as 10,000 amperes per square centimeter, and that the positve column may reach 10,000°K. with still higher temperatures existing in gas molecules within the positive space charge cloud.

Uncertainty as to whether such conditions do exist, and the values which should be assigned, makes it difficult to construct mechanisms of performance with any assurance of their accuracy. Himler-Cohn,[5] Yamamura,[4] and others, however, agree in general that as the mean-free path is lengthened by reduced pressure, electrons, with energy corresponding to the cathode fall, diffuse outward

[4] Yamamura, Sakae, Immobility phenomena and reverse driving phenomena of the electric arc: Jour. Appl. Phys., March 1950.
[5] Himler, Gary J. and George I. Cohn, The reverse blowout effect: Elec. Eng., Dec. 1948.
[6] Smith, Charles G., Retrograde arc motion of supersonic speed: Phys. Rev. 84: 1075, 1951.
[7] Druyvesteyn, M. J. and F. M. Penning: Rev. Mod. Phys. 12: 87, 1940.

into the positive space charge cloud. It seems probable that the loci of these electrons are bent by the transverse magnetic field, as shown in figure 4. Those diffusing to the left are sufficiently accelerated by the electric field to ionize gas molecules with which they collide. Those moving to the right are decelerated by the electric field, since they are moving opposite to its direction. Thus there is more ionization at the left side than at the right, which causes the cathode spot to migrate to the left, opposite to the pondermotive direction in which the arc column is normally driven by a magnetic field. When the force of the leftward-migration effect balances that of the normal pondermotive force, immobility of the arc occurs. When the leftward-migration forces exceed those of the rightward forces, retrograde movement results.

The velocity with which the arc is driven in the normal Ampere's law direction decreases with decrease in air pressure until the point of immobility is reached. It seems reasonable to assume that this effect results from the expansion of the arc under lowered pressure, which produces a greater damping effect. After the point of immobility has been passed, however, the velocity with which the arc is driven increases with decreased air pressure. It can only be assumed that this increase is the result of increased forces in the retrograde direction which more than balances the damping effect of the continued increase in volume occupied by the arc. Smith[6] has reported mercury arcs driven in retrograde, circular paths in radial magnetic fields at four times sonic velocities for the pressures used.

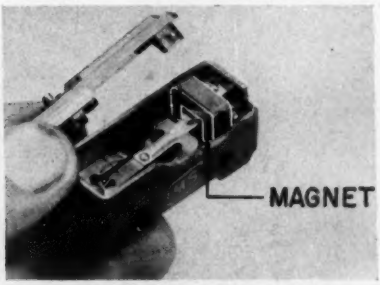


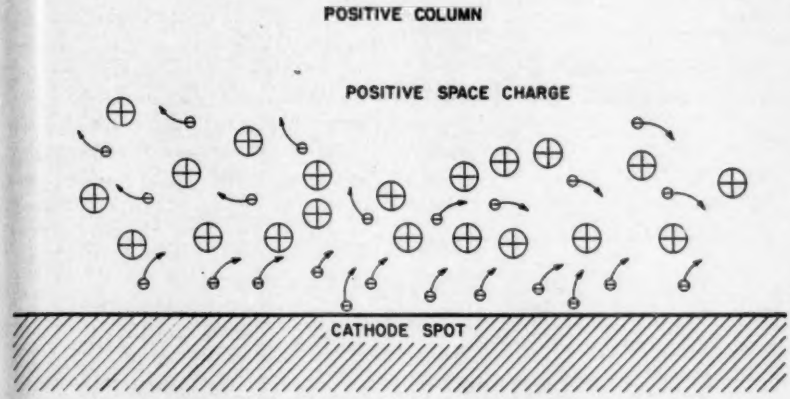
FIG. 3.—Commercial type of single-pole double-throw magnetic blowout switch rated at 10 amperes, 120 volts d-c at ground-level pressure. (Data supplied by Dallas.)

Increase in density of the transverse magnetic field decreases the radii of curvature of electron paths, thus causing effective ionization, of the type shown in figure 4, under conditions of shorter mean-free paths. This theory is supported by the observation that increasing the strength of the blowout field lowers the altitude at which immobility occurs.

It is interesting to note that there is a period of momentary arc immobility immediately following contact separation. The time of persistence of such immobility increases as the conditions of permanent immobility with contacts fully separated is approached.

There is the further phenomenon that a very short arc cannot be moved by a magnetic field. Such permanent immobility exists for arcs of 0.4 millimeter length in a field of 50 gauss and at 0.2 millimeter length in a field of 400 gauss.[4]

Yamamura[4] comments that both the momentary and permanent immobility of short arcs may be ex-



ENLARGED PICTURE OF THE CATHODE SPOT. ⊕ POSITIVE IONS. ⊖ ELECTRONS. THE MAGNETIC FIELD IS DIRECTED PERPENDICULARLY FROM THE FRONT TO THE BACK OF THE PAPER.

FIG. 4.—(Data supplied by Dallas.)

plained by high temperatures in the cathode spot under such conditions. Other workers, such as Dallas, question whether such conditions may not be more readily explained by the small force acting in the normal direction when its length is short,[8] and that the momentary effect may to some measure result from the fact that as contacts begin to separate the arc necessarily starts out by being short.

Regardless of the correctness of the theory behind these phenomena, they are of practical significance in that contact erosion produced by arcs which occur when contacts bounce, owing to the mechanical impact of closure, cannot be prevented by the use of blowout magnets, since such arcs, being both short in length and of short duration, are not moved by transverse magnetic flux.

Figure 5 shows that the area of arc reversal is at higher altitude when the magnetic field is asymmetrically shifted toward the cathode and vice versa. This observation bears out the theory that normal movement of the arc results from forces on the main column of the arc, and the retrograde leftward movement results from forces at the cathode end.

This effect can be demonstrated with the apparatus shown in figure 1, as the magnet is so located that flux density is greater at the lower electrode than at the upper. The arc moves as shown in figure 2 when the lower electrode in a denser field is the cathode. Reversal of the potential increases the altitude at which retrograde effect is seen.

Knowledge of this effect of nonuniform fields is of some practical value in building switches for use at altitude. Fortunately, however, many of the probelms of electrical switching at altitude are solved by hermetic sealing of switches under positive pressure of inert gas. This,

[8] The normal force moving an arc is proportional to the length of the arc times the current, times the mean flux density over its length.

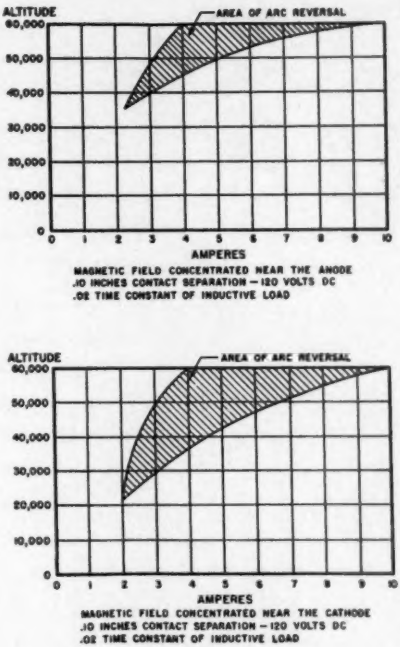


FIG. 5.—Effect of flux distribution over arc length. (Data supplied by Dallas.)

of course, completely avoids the puzzling problems of the immobile arc and some of the unknown effects at altitude of ozone, atmospheric composition, humidity, and ionization by cosmic rays. However, introducing mechanical actuation, free from variation under extremes of temperature and pressure, with certainty of permanent freedom from leak and the necessity of sealing enclosures without the use of either organic or ion-bearing solder flux, presents a series of challenging design, physical, chemical, and metallurgical problems which have not been completely solved. There has been sufficient progress, however, to enable many functions of high-flying aircraft to be carried out reliably by hermetically sealed, pressurized current-interrupting devices.

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Illinois Academy of Science Transactions, Vol. 45, 1952

VARIATION OF THE DIELECTRIC CONSTANT OF DIMETHYL SILICONE WITH TEMPERATURE

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Although the polysiloxanes constitute a relatively new family of synthetic compounds, research into the chemical and physical characteristics of these polymers has already produced a considerable body of published literature.

Liquid dimethyl polysiloxanes have received much of the attention directed toward the polysiloxane group. These materials are distinguished by tetravalent silicon atoms, each of which is linked to two methyl groups and two oxygen atoms, the oxygen-silicon linkages forming a chain molecule analogous to the carbon-carbon linkages of the hydrocarbon oils.

This investigation was undertaken as part of a joint research agreement between the Physics Department of Southern Illinois University, and the Sangamo Electric Company, Capacitor Division, at Ordill, Illinois. Its aim was to obtain information concerning the physical properties of dimethyl silicone oils which would be of use in determining the advisability of utilizing them as impregnating compounds for oil-impregnated capacitors. Three viscosities, 20 centistoke, 50 centistoke, and 350 centistoke, were selected as offering more promise than other viscosities for use as impregnating compounds.

Silicone oils manufactured by the Dow Corning Corporation of Midland, Michigan, were used. All measurements were made at 1000 cycles per second, because information released by the manufacturer indicated that there was no appreciable change in the dielectric constant with variations in frequency below frequencies of the order of 10^8 cycles per second, frequencies beyond the range of most "high frequency" laboratory equipment, and far outside the range of standard equipment. The temperature range investigated extended from—73°C. to 160°C.

The apparatus consisted of a General Radio Type 716-C capacitance bridge, with a General Radio Type 722-M precision condenser, a General Radio Type 1302-A oscillator as source, and a General Radio Type 1231-B amplifier and null-detector. Measurements above room temperature were taken with a Sargent 850-watt electric oven. Measurements below room temperature were taken with dry ice and a dry ice-acetone mixture as cooling agents. A capacitance test cell, constructed according to standards set up by the American Society for Testing Materials, was used for the capacitance measurements.

The "substitution method" was used with the bridge. The bridge is first balanced without the unknown capacitor. Then the unknown is connected in parallel with the balancing capacitor of the bridge, and the

bridge again balanced. The capacity of the unknown is given by the difference between the first and second settings of the balancing capacitor of the bridge.

The maximum possible error of the bridge when the substitution method is used is 2 micro micro farads. However, with the use of a correction chart, this may be reduced to 0.5 micro micro farad, making a maximum error of 0.8 percent. If a conservative estimate of the maximum error introduced by a temperature measurement error is added to this, the total maximum possible error is one percent. In determining the dielectric constant of the oil, the capacitance of the test cell, filled with oil, is divided by the capacitance of the cell, with air as the dielectric. (The capacitance in air may be taken as the capacitance in vacuum, because the dielectric constant of air is 1.0006 under standard conditions of temperature and pressure.) If there were an error in the determination of the value of the capacitance of the test cell in air, this error would show up in the experimental curves as a constant vertical displacement.

The experimental values for room temperature agreed well with the published values, in fact, well within one percent. There was a small amount of data available over the temperature range 25°C. to 145°C. This material also checked well with the experimental results. The values for the dielectric constants over the range 145°C. to 160°C. and —73°C. to 25°C., however, represent, as far as available sources are concerned, new information.

Two sets of data were taken for each oil: one over the temperature range above room temperature, and one over the lower temperature range. A small overlapping of the two sets of data was obtained by preheating the test cell before it was placed in the cold chamber. The agreement between the two sets is good for 50 and 350 centistoke silicone. However, the disagreement between the two sets for 20 centistoke is only a difference of about one percent for the two points most widely separated—a difference well within the maximum possible difference of two percent.

The curves show a smooth variation over the entire temperature range studied. This is an interesting result, because mineral oils, which are widely used as impregnating compounds for oil-impregnated capacitors show a drop of about ten percent at their "freezing" point. The "freezing," or solidification point, of dimethyl silicone oil varies with the viscosity, but for the oils investigated it lies within the —40°C. to —60°C. temperature range.

In conclusion, from the point of variation of dielectric constant with temperature, the silicones seem promising as an impregnating compound for oil-impregnated capacitors that would be used in installations subjected to wide ranges in temperature.

Illinois Academy of Science Transactions, Vol. 45, 1952

PSYCHOLOGY AND EDUCATION

THE PHYSICAL GROWTH OF 4-H CLUB MEMBERS*

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One H inscribed on the clover leaf emblem of the 4-H clubs means health. Good health has long been an objective of the club, and club members pledge "my health to better living."

Better living is more than absence from disease—it is a positive state of physical fitness and well-being. It consists of at least four factors:[1] 1. growth and body development, 2. organic fitness, 3. motor fitness, and 4. body protection. All these factors are considered in the health and fitness program for 4-H members in Illinois. However, this report is limited to the problems, and particularly the measurement, of growth and body development.

The bases for good health are conditions favorable to both physical and mental growth. Dr. Krogman[2], interested in growth of body, said, "We are obliged to take measures to determine whether or not our youth are reaching that goal." Weighing and measuring are the usual methods of determining whether boys and girls are developing normally.

More emphasis has been put upon retarded than upon accelerated growth. Wetzel[3] found growth failure in 30 percent of the children and recommended medical examinations in order to determine the causes. He cited a case of a girl who incurred a 259,000 calorie fuel debt during three years of lagging growth. It took ten months of careful treatment which cost $850 to bring her back to a normal growth pattern.

Recently emphasis is being placed upon the losses in adult life due to obesity, much of which originates in faulty habits of eating and exercising learned during youth. Farmers particularly see fat as desirable, because they see fat hogs, cattle, and sheep going to market and thus fattening their pocketbooks. To them a fat animal is a healthy animal. If human beings were to be marketed as soon as they are grown, fat on them might be as profitable as on cattle. But with human beings and horses, a long work life is desirable, and fat is a dangerous handicap.

If some standard was available and if measurements were made

* The help in statistical analyses of W. Touchberry and E. E. Hixson of the Dairy Science Dept. and D. R. Saunders of the Psychology Dept., Univ. of Ill., is gratefully acknowledged.

[1] Cureton, Thomas K., What is physical fitness?: Jour. Health and Phys. Ed. 3:111, March, 1945.
Hall, D. M., Illinois 4-H club members go all out for fitness: Rural Sociol. 12:61, 1947.
Hall, D. M., Fitness can be fun: Better Farming Methods, p. 29, Feb. 1947.

[2] Krogman, W. M., Growth of man: Lab. Biol. 20:1-967, 1941.

[3] Wetzel, Norman C., Treatment of growth failure in children: Cleveland, Ohio, N.E.A. Service Inc., 1948.

quarterly or semiannually, as Merideth[4] recommends, we might more easily detect poor growth. Furthermore, the consequences which the British Inquiry[5] found to be "physical deterioration in the adult population" could have been avoided had the poor growth been discovered and treated in childhood.

Height and weight have long been used as measures of growth, but many who have used height-weight-age tables have felt that the tables did not take into account differences in body type and therefore were not entirely satisfactory in discovering those needing treatment. Several attempts have been made to correct height-weight tables for body type. Shuttleworth[6] proposed differentiation by maturity classes because he found different growth patterns for individuals who mature early and those who mature late. Jorgenson and Hatlestad[7] calculated 33 different indexes for body type and concluded the ponderal index ($\sqrt[3]{\text{Weight/Height}}$) devised by Levi to be the most satisfactory. McCloy[8] found this index and Wolff[9] found a closely related one (Weight/Height^3) to vary less with age than other height-weight combinations.

We plotted the ponderal index on Wetzel's grid[10] and found it corresponded closely with his physique classes.[11]

The Growth Chart

The average weight-by-height classes for age taken from the Baldwin-Wood tables plotted a very slight S-shaped curve on double logarithmic paper. The ponderal indexes for the different weight-height classes were curvilinear, too.[12]

The ponderal indexes for the average height-weight classes from Baldwin-Wood tables showed nearly a straight line on the Growth Chart for ages 10 to 18 years. The Illinois data for 12,000 cases followed the 76-type channel closely between ages 10 to 19 years. Both the Baldwin-Wood and Illinois data were so-called cross-sectional data.

The Harvard data,[13] repeated measures on the same persons over a 10-year period, were longitudinal data. These data were identified by the period of most rapid growth. Approximately 85 percent of the boys and girls measured completed their spurt in height within one year. For those making a rapid gain in height, the index showed a drop, sometimes as much as 2 points, and then returned to its former figure.

Brody[14] states that the acceleration in height represents a compensation in growth for those children who were relatively undernourished earlier in life. If this is the case, then

[4] Merideth, H. V., The reliability of anthropometric measurements: Child Devel. 7:262-72, 1936.
[5] Mumford, A. A., Healthy growth: London, Oxford University Press, 1927.
[6] Shuttleworth, Frank K., Physical and mental growth of boys and girls: Soc. for Res. in Child Devel. Mono. V4[3] and V2[5], Washington, D. C., 1939.
[7] Jorgenson, N. M., and Hatlestad, S. Lucille, The determination and measurement of body build in men and women college students: Res. Quart. 11:60, Dec. 1940.
[8] McCloy, Charles H., Appraising physical status; the selection of measurements: Studies in Child Welfare 12:2, University of Iowa, Iowa City, 1936.
[9] Wolff, George, A study of height in white school children: Child Devel. 13:65, 1942.
[10] Wetzel, Norman C., Physical fitness in terms of physique, development and basal metabolism: Jour. Am. Med. Assoc. 116:1189, March 22, 1941.
[11] Hall, D. M., and Wittenborn, J. R., Motor fitness tests for farm boys: Res. Quart. 13:432, Dec. 1942.
[12] Hall, D. M., Keeping fit: Ill. Exten. Serv. Cir. 615, Univ. of Ill., Urbana, 1946.
[13] Dearborn, Walter F., Rothney, John W. M., and Shuttleworth, Frank K., Data on the growth of public school children: Mono. 1, Soc. for Res. on Child Devel. vol. 3, Nat. Res. Council, Washington, D. C., 1938.
[14] Brody, Samuel, Bioenergetics and growth: New York, Reinhold, 1945.

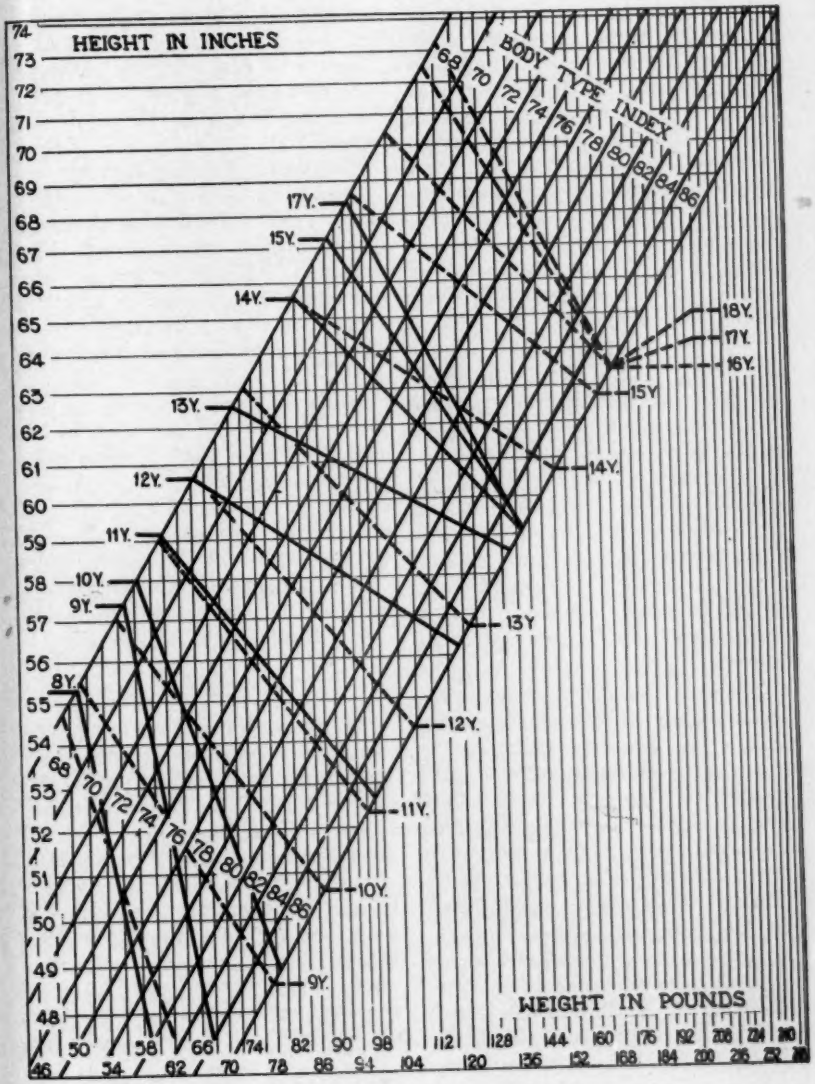
HEIGHT IN INCHES
BODY TYPE INDEX
68
70
72
74
76
78
80
82
84
86
17Y.
15Y.
14Y.
13Y.
12Y.
11Y.
10Y.
9Y.
8Y.
18Y.
17Y.
16Y.
15Y
14Y.
13Y
12Y.
11Y.
10Y.
9Y.
WEIGHT IN POUNDS

FIG. 1.

healthy children should show no spurt or drop in index value.

During the period 10 to 17 years of age, the average ponderal index for the Harvard boys remained nearly constant, but for the girls it increased about two points after 14 years. The evidence on healthy growth indicates that the ponderal index should remain relatively constant after 10 years of age. Furthermore, if a child has grown to maturity on his schedule, any change in weight and index thereafter indicates a loss in fitness.

The two measures of growth, height and weight, when combined into the ponderal index and plotted on double logarithmic paper, formed a series of linear channels. Since the index is constant between 10 and 19 years of age, one is able to identify deviations from the normal by plotting a person's growth in weight and height on figure 1. Frequent plots of height-weight should form a straight line within the body-type channel.

At this point one naturally asks, "How far up the channel should the growth line progress each year?" The answer is found in the lines crossing the body-type channels. The solid lines for girls, the dashed lines for boys, show up-channel growth progress from year to year.

These cross lines were adjusted slightly from two regression equations. First, from about 14,000 cards punched from the Harvard data, we calculated as if these were cross-sectional data and predicted weight for each height-body type-age group for both boys and girls. Then we did the same for the Illinois cross-sectional data. The predicted weights were almost identical. The predicted weights for each age were plotted on the body-type chart and a straight line was drawn through the points. These cross-channel lines show the different growth rates for different body types during the same age period.

The body-type chart may serve as a screening device to select those who need further examination. Those persons whose growth lines deviate to the right or left or whose acceleration up-channel is very different from the indicated amounts should be examined to determine the causes.

Other signs of unhealthy growth given by Turner[15] are pale, sallow skin, dull hair, dark circles under eyes, thin spindly arms and legs, stringy or flabby muscles, pinched or anxious expression, dull eyes, slouchy posture, pale mucous membranes, decayed teeth, spongy gums, nervousness, poor concentration ability, disturbed sleep, and obesity.

Growth Cycles

To measure healthy growth one must understand the growth cycle. The growth cycle is curvilinear, although during a short period it may appear as a straight line. Courtis[16] describes the growth cycle as a period of specific maturation during which all the elements and acting forces were constant. When modifying influences act, a new cycle is begun.

[15] Turner, C. S., Precision and reliability of underweight measurements: Am. Jour. Health 19:669, 1929.

[16] Courtis, S. A., What is a growth cycle?: Growth 1:155, 1937.

Courtis, S. A., Maturation units for the measurement of growth: School and Society, Nov. 16, 1929.

Courtis, S. A., Growth and development in children: Advances in health education: Rept. of 7th Health Ed. Conf., Ann Arbor, Michigan, 1934.

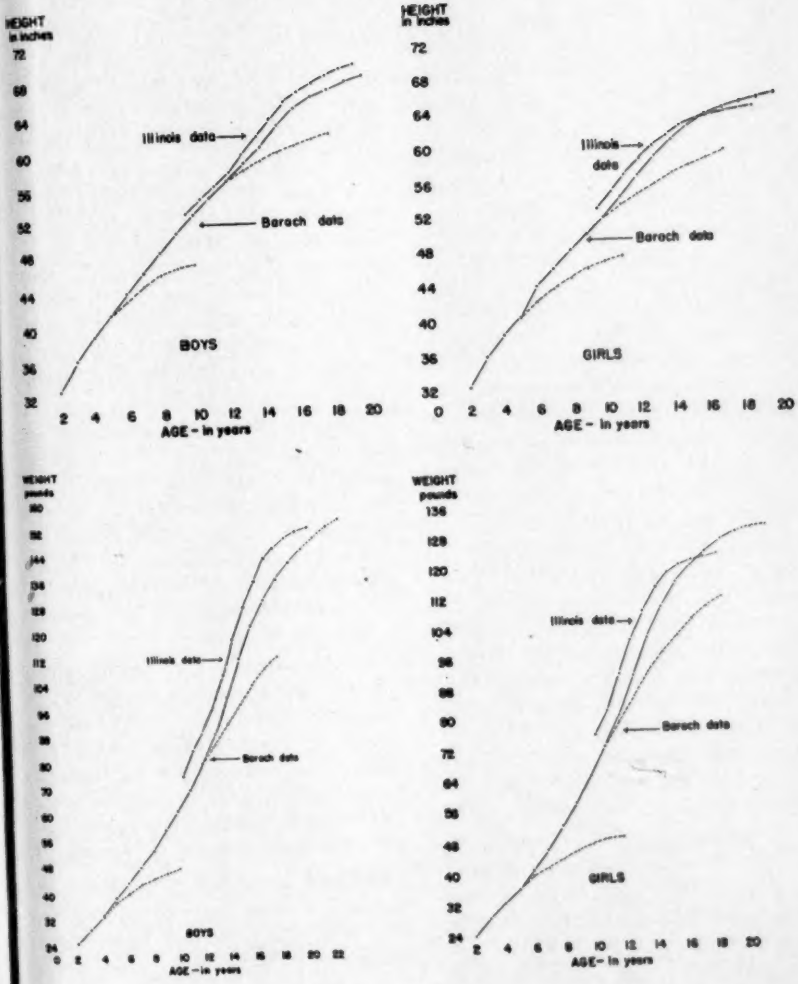
HEIGHT in inches
Illinois data
Baroch data
BOYS
AGE - in years
HEIGHT in inches
Illinois data
Baroch data
GIRLS
AGE - in years
WEIGHT pounds
Illinois data
Baroch data
BOYS
AGE - in years
WEIGHT pounds
Illinois data
Baroch data
GIRLS
AGE - in years

FIG. 2.

Courtis writes the equation $Y=Ki^{rt}$ in which K is the maximum at maturity, i is the degree of development at the beginning of the cycle, r is the rate, t is time and Y is the achieved development at any specified time. Courtis calls the growth unit an "isochron." He changes isochron to percent by means of a table, and then wrote the growth equation $Y=K\ [rt+i]$ which he solved by simple arithmetic.

Scammon[17] showed a compound curve for height which consisted of three cycles, namely infancy, childhood, and adolescence. Theoretically any change in the conditions might cause a cycle, but a true cycle must be established by supporting evidence, such as the disappearance of baby fat, the growth in muscular tissue, the atrophy of the thymus, and the development of the genitalia during the adolescence cycle.[18]

Barach[19] summarized height and weight data for over 400,000 cases, which Baker[20] then smoothed into growth curves. We calculated the isochronic growth curves for the Barach data and have plotted them along with the curves for Illinois boys and girls (fig. 2). These are compound curves, showing three cycles for Barach's data and two cycles for the Illinois data.

A person's best weight is his weight when he is in good physical condition. This means bony, muscular, and fatty tissues must be properly proportioned. Theoretically, the weight of a person in good condition is proportional to the size of his skeleton. If we could determine how much a person should weigh, and then use this weight in determining his body type, we could then determine which channel his growth line should follow as he grows older. This is our next problem.

We are taking certain skeletal measures which McCloy[21] said "have demonstrated their right to be included in the final battery" for predicting weight. These we propose to work into a multiple regression equation for predicting the weight of a person in good health. This study will be reported later.

Our sample data were collected at "Keeping Fit" field days, which presumably attracted those interested in physical activity. We judged them to be neither inferior nor superior in condition. However, we intend to exclude from the regression equations persons suspected of being at low fitness levels.

Sound programs are built upon facts. If we desire a sound physique —a sturdy body properly proportioned in bone, muscle, and fat— which can do a day's work without exhausting its reserves, then we must collect and interpret for boys and girls the facts about their growth.

It seems clear that if normal persons are to grow according to schedule, they must do at least three things:

1. They must eat the proper amounts of the right kinds of foods.

[17] Scammon, R. E., The first seriatim study of human growth: Am. Jour. Phys. Anthro. 10:329, 1927.

[18] Shuttleworth, Frank K., The adolescent period: Mono. of Soc. for Res. in Child Devel., vol. 3, no. 3, Nat. Res. Council, Washington, D. C., 1938.

[19] Barach, J. H., Normal standards in the treatment of young persons with diabetes: Am. Jour. Dis. Children 69:92, 1945.

[20] Baker, G. A., Graduation of growth curves: Growth 9:299, 1945.

[21] McCloy, Charles H., Appraising physical status: the selection of measurements: Studies in Child Welfare 12:2, University of Iowa, Iowa City, 1936.

2. They must take plenty of exercise.

3. They must get enough sleep.

Nature and society conspire to interest us in the way we are growing up. We have many muscular tasks to learn. During our first six years we must learn to eat, talk, walk, run, and otherwise control our bodies. During the next six years, we must learn to coordinate our movements more precisely. During the third six-year period, our interests turn to physique, strength, attractiveness, stamina, and motor skills. These are some of the developmental tasks[22] each of us must learn if he grows up properly.

"Optimal growth," declared Dr. Mills,[23] "seems to require an active tissue combustion level. The body being only 20-25 percent efficient, and being very sensitive to the internal accumulation of heat, must and does bank its fires when any prolonged difficulty in heat dissipation is encountered. Such finds a coincidental reduction, in rate of growth and development, in resistance to infection, in production of immune bodies and a drop in the energy for thought and action."

It is essential that we know and control the conditions of healthy growth.

[22] Havighurst, R. J., Developmental tasks and education: Univ. of Chi. Press, Chicago, 1948.

[23] Mills, C. A., Further evidence of reversal in human growth tide: Human Biol. 13:363, 1941.

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SOCIAL SCIENCE

FOLKWAYS AND MORES IN A GREEK-AMERICAN COMMUNITY

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The primary purpose of this paper is to demonstrate a method of research introduced into social science by Wilhelm Dilthey and his coworker, Georg Simmel. The study covers a community designated as "American City," which is located about fifty miles north of Chicago. The group selected is made up of Greek immigrants who came to the United States during the early decades of the 20th century.

The publication of Dilthey's "Einleitung in die Geisteswissenschaften" represents a milestone on the long road which has led to the "sociology that seeks to understand." This "*verstehende Soziologie,*" as Dilthey called it, is a far cry from the grandiose systems of Auguste Comte, Herbert Spencer, or Vilfredo Pareto. The type of research sponsored by Dilthey and Simmel may, however, be regarded as complementary to the method which Znaniecki calls "analytical induction."

Dilthey steadfastly maintained that there must be a distinction between the methodology applicable in the social sciences and the methodological approach proper to the purely natural sciences. The *Geisteswissenschaften,* in Dilthey's definition, included all the social sciences—those sciences which study human beings as they actually are.[1] Thus we are compelled to take into account not only behavior, both social and individual, but also the *Geist*—the mental, volitional, and emotional aspects of the total personality. Nor can the factor of motivation be overlooked, although the "behaviorist" may find it convenient for scientific purposes merely to observe and describe the various forms of social behavior.

The proper work of the research sociologist, as Dilthey and Simmel see it, is the investigation of the psychic life of individuals who live in the everyday world of normal social relationships.[2] It can be effected through a process sometimes called *Einfühlung* or empathy. As Dilthey points out, will, as well as thought, must function in this type of sociological research.

While analytical induction aims at detecting "a set of conditions which *always* accompany"[3] certain social phenomena, for example drug

[1] Social scientists who have been influenced by Dilthey's concept of "*Geisteswissenschaften,*" for example: Simmel, Windelband, Rickert, Troeltsch in Germany, and F. A. Christie in the United States, have always insisted that the human personality is "an individual structure, never repeated, to be accepted as offered." *See* F. A. Christie, Analysis No. 28, Methods in Social Science: Univ. of Chicago Press, p. 416, 1931.

[2] Wilhelm Dilthey, *Gesammelte Schriften, I. Band, Einleitung in die Geisteswissenschaften,* Leipsig und Berlin, 1922, p. 420.

[3] W. S. Robinson, The logical structure of analytic induction: Am. Soc. Rev., vol. 16, Dec. 1951, p. 815.

addiction[4] or embezzlement,[5] the Dilthey method lends itself better to the study of social organization than to that of social disorganization. Though the investigation of conflicting folkways and mores will not lead to "universal statements of the form 'All S are P,'" it results in the understanding of the cultural pattern characteristic of American industrial communities. It also leads to the conclusion that, in matters of normal or ordinary social behavior (as contrasted with socially pathological phenomena like drug addiction or embezzlement), the actions of individuals living under "the conditions represented by social relations" are not predictable. One girl brought up along strictly Greek Orthodox lines will docilely follow the endogamous traditions of the group, while another, similarly "conditioned" will reject the older folkways and mores in relation to marriage.

In *The Method of Sociology*, Znaniecki does not overlook or decry the Dilthey-Simmel approach to the study of social reality, as might be deduced from Robinson's statement that the co-author of *The Polish Peasant* "holds that analytic induction is the true method of the physical and biological sciences, and that it ought to be the method of the social sciences too."[6] The following passage[7] from Znaniecki's *Method of Sociology* not only indicates his appreciation of Dilthey's approach to social reality but also summarizes the method he calls "mental identification":

> Vicarious experience has always been used by sociologists. Certain schools of sociology have even extolled it as the main, if not the unique source of sociological knowledge. Thus, according to the principle promulgated by Dilthey, the proper method of all cultural sciences is internal synthetic *understanding* as contrasted with external observation and analytical explanation used by the sciences of nature; we live inside the cultural world and mental identification with other cultural agents gives us the only adequate knowledge of their cultural life.

"American City" is a happy hunting ground for the cultural anthropologist and the sociological investigator. A highly industrialized community, it has attracted immigrants from almost every European nation and also a large number of Negro families from the South. Here, in close proximity, live Poles, Italians, Croatians, Slovenes, Jews, Mexicans, and Greeks, as well as "Americans of African descent."[8] There are also numerous representatives of the "old immigration": those of French, Irish, English, and Dutch descent who constitute a sort of political and social in-group in American City.

The present study[9] had its inception in a student-professor study of the Mexicans living in American City. Two years later, the writer was told by a Greek-American: "If you really want to study the Greeks, the only way to do it is to work in a Greek restaurant." This advice was followed, and in the course of her activities as coffeemaker, unofficial secretary and even "literary" adviser to the proprietor of the restaurant we shall call "The My-

[4] D. R. Cressey, Opiate addiction: Bloomington, Indiana, 1947.
[5] D. R. Cressey, Criminal Violation of Financial Trust: Am. Soc. Rev., vol. 15, Dec. 1950.
[6] W. S. Robinson, *op. cit.* p. 812.
[7] Florian Znaniecki, *The method of sociology*: Farrar and Rinehart, 1934, p. 169.

[8] This term was found to be the one preferred by a highly educated Negro doctor living in American City.
[9] The present article forms part of the general project which covers the various ethnic groups enumerated above.

cenia," the writer became part and parcel, *pro tem.*, of Greek-American life in an industrial community.

The restaurant is owned by a man who will be called "Thorius" in this article, and the fancy French-looking chef in the kitchen was his older brother. One of the Greek waitresses, who will be designated as "Venus" on account of her unusual pulchritude, and the writer became excellent friends from the very start. The life story of Venus proved of unusual sociological interest, and the *Einfühlung* process was very easy in this particular instance.

A methodological device used by Warner, namely, to compress the "lives of several individuals" into "that of one fictive person"[10] was not adopted in the present study. Since the Greek-Americans of American City were found to be not only law abiding citizens but as normal a group as could be found anywhere it was not considered necessary to do more than change the names of actual persons. Nor does the present study seek to demonstrate what Warner calls "the magnificent history of the adjustment of the ethnic groups to American life." The findings, in general, substantiate Simmel's hypothesis that the impulse to preserve the integrity of the social group is one of the strongest drives in the total human personality.

Like the Armenians and the Jews, the Greek-Americans in the community tend to preserve their cultural pattern. The two social institutions which help the Greeks maintain their cultural identity are the Greek Orthodox Church and the "Greek School." For example, one is not really married unless the ritual is performed in the traditional Greek style. Thus a system of modified endogamy, reinforced by religious sanctions, still prevails to some extent.

The Greek School is also an important agency in the cultural group. The proprietor of the Mycenia, who had married the Greek-American daughter of a Greek mother whose marriage had been arranged in the old-world fashion, became the proud father of a baby boy during the period covered by the investigation. Almost as soon as his son was born, Thorius announced his intention of sending Christos to a Greek School, as well as to public school. His older brothers, however, had, on coming to the United States, married outside the group. The marriages were not altogether successful; one had ended in divorce, the others were average in compatibility.

Whereas the Greek male immigrant may or may not follow the endogamous tradition, as his fancy dictates, considerable pressure has been, and still is, put on the women to conform to the Orthodox traditions. A girl brought up in a Greek-American family is expected to obey her father's wishes in respect to marriage, and many girls in American City do conform. There is, in this area, a definite cultural conflict, as the following findings indicate.

Venus's father came to the United States from Greece at the age of fourteen. He married a Polish-American girl, but proceeded to bring up his family along completely

[10] See W. L. Warner and L. Srole, The Social Systems of American Ethnic Groups: Yale Univ. Press, 1945, p. 3.

Greek Orthodox lines. At the age of four Venus was sent to the local Greek School which, she said, was operated by the Greek Orthodox Church. At home she always spoke Greek with her father, but English with her mother. In Venus' own words:

> I learned to read Greek at school, and learned quickly, or else I got tanned. In that school there were usually old teachers who were kicked out of the Church. That's the truth. Was I happy at school? Well, at home everything was nice, and I was kind of proud of myself. When I was six, I went to regular school, but kept on going to the Greek School three times a week. I did not go to high school. My father could not afford it and girls came out pregnant, he said, if they went to high school in American City. But he let my brothers go.

Venus began her career as a wage earner at the age of thirteen. Like many other immigrants' children interviewed, she worked first in private homes, washing and ironing, and doing household chores.

> I earned twenty-five cents an hour and worked six days a week. I was heart-broken because I had been made to leave school. When I was fifteen I went to work in a dime store. Yes, I *was* under age, legally, but a kind man lied about my age.

In accordance with the accepted folkways and mores,[11] Venus (who was promoted to assistant manager of the lunch counter as soon as she was sixteen) always brought home her pay check, which was promptly spent on things for the home. These included, she said, a refrigerator and clothes for her baby brother. "We refurnished the whole house."

At this point it should be stressed that the father's right to the money earned by his children is one of the most salient characteristics of the customs prevalent in the Greece known to the older generation of immigrants. In one instance, the unquestioned right of the father to his son's earnings extended to the payment by one of the interviewees of a debt of honor owed by his father. This young man was sent to the United States at the age of eighteen to earn sufficient money in American City to pay a debt his father owed to a Greek monastery. In his own words:

> The head of the monastery was my father's cousin, and one of my father's friends had leased some land from the monastery at three thousand drachmas for three years, about a hundred acres in all. This man defaulted, and my father had signed the bond for him, and so my father owed the money to the monastery and he had to pay it. So he sent me to the United States to earn the money. I landed in New York and came to work in one of the factories near American City, as a cord maker, at $1.50 a day. We worked ten hours a day, six days a week. In 1912 we were getting $32 a week . . . In September, 1912, I went back to Greece and gave my father the money to pay the debt on the land to the monks.

He returned to American City in 1917, after several years of service as a sergeant in the Greek army, which he joined as soon as he had repaid his father's debt of honor. He set up for himself in his father's trade of shoemaking and became an American citizen in 1925. Partly as a result of his first-hand knowledge of the writings of Karl Marx, and partly on account of his boyhood grudge against the monks, he has left the Greek Orthodox Church and has discarded the traditions of his childhood, except so far as the Greek language is concerned. His children were brought up in the American way of life, whereas Venus and her brothers were educated, as we have indicated, in strictly Greek style. It

[11] Cf. the findings of Warner, *op. cit.*, p. 129.

was only when Venus lost her heart to an American service man during the Second World War, that she finally cut loose from the folkways and mores of her ethnic group.

Venus was summoned home to work in her father's restaurant (purchased largely out of her dime store earnings) shortly before her eighteenth birthday. During her adolescence she had been constantly escorted wherever she went, by her father, her Greek uncles, and even by the erstwhile baby brother. Several attempts had been made to marry her off in the old-fashioned way. One of the men who aspired to an arranged marriage with Venus was, she said, "sixty, if he was a day. That time I put my hair in pigtails, and came into the room looking about fifteen, sucking a lollipop." Her father and his male relatives had thwarted her every attempt to become part of the American community. Finally, the high-spirited Greek girl eloped with an American service man she had met while waiting on him in the restaurant. By that time she was nearly nineteen. She had never had a date.

An Italian boy with whom she had fallen secretly in love had been fired from the restaurant because she had walked down the street with him. The climax came when Venus accepted an invitation to go dancing in Chicago with the man who is now her husband. She informed her family of her intention.

> My father raised quite a ruckus. He picked up a knife and grabbed me by the throat. He was going to cut my throat. 'Father,' I said, 'Unless you let me really live a life, you might just as well kill me.' My mother grabbed the knife. The knife cut her hand. My father saw the blood. I pushed him so hard, he lit up against the refrigerator. I figured if I gave in then I would be doomed. Mother finally made him see that, if we went on like this, I wouldn't be any good to any one.

This melodramatic but authentic incident occurred at midnight, on the day before Venus' first date. The year was 1943. To continue in her own words:

> I went to bed at one and got up for work at five-thirty. I worked until about six o'clock that evening. I didn't work too late. Then I walked to my date with (Jo) at the railroad station, and went to Chicago with him. I had never danced with a man. I had never been to Chicago before except with my parents. . . . Jo had a ring in his hand that I had admired at the restaurant. It was an old Swiss ring. . . . He proposed marriage to me. I cried. I didn't only cry; I accepted the proposal. Seventeen days later we were married. We eloped to X city, and were married in a little chapel. That was in August, 1943. Jo was twenty-one and I was nineteen.

Venus's family, when confronted with a *fait accompli*, accepted the situation. When Jo was sent overseas, the Greek-American girl, now married to the man whose ethnic origin she described as "Duke's mixture" (Pennsylvania Dutch, Irish, and English), returned to work in her father's restaurant. Her Greek friends and relatives assumed, quite erroneously, that Jo "had" to marry her. In point of fact, Venus had lived more like a convent novice than a typical American adolescent prior to her marriage. When Jo came out of the armed services, he worked for a while in the restaurant; but Venus, as she said, "fired him. I knew the ropes, and he didn't and it was spoiling our relationship."

One of the reasons why "Venus" appears as a sort of "bright particular star" in this article is that the authenticity of her story was vouched

for by reliable witnesses, whereas some of the other material collected turned out to be of doubtful factual value. This was especially the case in respect to what might be called a "Greek myth" that had been published *as fact* in a popular magazine.

Although it is not wholly accurate to regard the "tall story" as part of the Greek folkways and mores, the hypothesis that the literature handed down by way of the Homeric tradition exercises a definite influence on the social life of the group deserves consideration.

According to the "True Saga," which had appeared in print a few years before the present writer embarked upon her sociological career in the Mycenia, there was once a valiant young Greek called Thorius who journeyed across the Atlantic Ocean by means of a simple device: stowing away in a lifeboat. After a goodly number of heroic adventures which made an excellent news story he reached his destination and ultimately achieved fame and fortune in a manner well befitting the Greek literary tradition.

The True Saga was written up by an American journalist, and the magazine was presented to the writer by Thorius upon the occasion of her first visit to the Mycenia. Soon after she began to work in the Greek restaurant her sociological skepticism was aroused by the casual remarks of her co-workers. One of the non-Greeks, who had known Thorius for nearly twenty years (having married into the Greek-American group) remarked forcefully: "Ananias has nothing on *him.*" Another employee said: "He has told that story so often that he has almost come to believe it himself." The "empathizing" sociologist was somewhat baffled. And it must be added that she had "empathized" herself so fully into the social situation that she had a sense of loyalty to the Greek employer who had proved unexpectedly co-operative and hospitable.

Sociological conscience, however, prevailed. A prolonged, rather painstaking enquiry led to the conclusion that the owner of the Mycenia had arrived in the United States in the ordinary, law-abiding way, mainly as a result of the efforts of his older brothers, who had paid his passage. After his arrival in American City, one of these brothers had taken the young Thorius into business with him. When the business was threatened with complete shipwreck during the Depression, the youngest brother began to take over, partly on account of his stronger physique and less exhausted physical and mental condition. (The life of the early Greek immigrants was almost unbelievably strenuous, and the older brothers showed unmistakable signs of excessive fatigue.)

The youngest brother had succeeded in weathering the storms of the depression era, and, by 1952, had become not only a successful entrepreneur but also the leading representative of the Greek-American community. The sensational story of his early adventures, which read like a typical Horatio Alger publication, was a mixture of American journalism and what might be called Greek myth. After having worked for a few weeks in the Mycenia, the investigator began to take it as a matter of course that, after the replete customers had departed, the

Greek-American clan would sit drinking coffee and discuss the fictional aspects of the True Saga. Frequently these discussions were carried on within earshot of Thorius himself, who appeared to be quite complacent about the whole matter.

In some respects the Mycenia resembled the traditional Greek coffee houses described by Warner in *The Social Systems of American Ethnic Groups.*[12] These are referred to, by one of Warner's Greek interviewees, as "joking places."

In an authentic Greek coffee house, the males of the group "sit around, joke with each other, call each other names, all in good fun. It is all understood. But when one goes into a Greek's house, he won't joke with the husband or anything like that. He keeps the jokes for the joking places. In the home they are dignified."[13]

The truth of this statement became apparent to the present writer at the time of the birth of Christos, the son of the hero of the mythical "True Saga." All the traditional ritual was observed with impressive formality, including the custom of insisting that the mother of the newborn baby refrain from visiting any family or going to church until the period of seclusion had terminated. This period lasts forty days, after which the baby is taken to church to be baptized. When questioned as to the reason for this rule, the parents were unable to explain it; they only knew that it had to be observed in the Greek Church community. Nor could any other of the Greeks interviewed shed any light on the question. In point of fact, the rule derives from the Mosaic law, as the present writer discovered through the ecclesiastics consulted.[14]

The observance of these and other traditional rules, enforced by the Greek Church, tends to preserve the cultural identity of the ethnic group. As Warner shows, the Greek Orthodox Church was, for centuries, the focal point of Greek national life, up to the time of the liberation from the Turkish empire in 1823.

Another significant aspect of Greek traditions and one which stimulates the impulse to defend the social group living in America and to preserve its cultural identity, is a proud sense of close relationship to the classical culture of ancient Greece. While the language of modern Greece is very different from that used by Plato and Aristotle, it must not be forgotten that many of the Greek lads who came to the United States during the first decades of the present century had studied classical Greek at school. Plato's *Republic* stands on the book shelves of Thorius' comfortable home in American City, and sections of this immortal classic were read together by Thorius and the writer one rainy afternoon when the Mycenia was closed for the day. He read the Greek text aloud and she followed in the Jowett translation.

The justifiable cultural pride of the Greeks who settle in America should be taken into account when estimating the conflict, at times very acute, between the Greek folkways and mores and the American way of life.

[12] Warner, *op. cit.*, p. 130.
[13] Warner and Srole, *op. cit.*, pp. 259-260.
[14] Leviticus, Chapter XII. "And in the eighth day the flesh of his foreskin shall be circumcised. And she shall then continue in the blood of her purifying three and thirty days."

Illinois Academy of Science Transactions, Vol. 45, 1952

ZOOLOGY

PAIRED FACTORS AND MASTER FACTORS IN ENVIRONMENTAL RELATIONS

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Whoever said that in experimental work only one factor is to be varied or tested at one time—all other conditions in the experiment and control to be the same—covered only about 10 percent of the story so far as living organisms are concerned. It is now about 55 years since Professor Abbe of the U. S. Weather Bureau (1898) made some studies of the sensation of comfort. There was, however, so much variation among individuals that the author illustrated the principles involved by a statement of his own sensations (fig. 1). It is evident here that humidity and temperature are paired. This is understandable by reference to the temperature regulation mechanism of warm blooded animals, especially man (Best and Taylor, 1949, Chap. 25). Huntington (1919) studied human deaths and found relative humidity and temperature paired; fewest deaths occurred at 80 percent humidity and 65° F. temperature. This probably came about through lessened work to maintain the body temperature at normal.

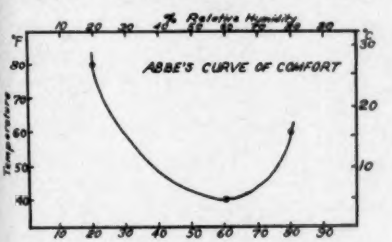

FIG. 1.—Abbe's personal comfort chart. As named in European literature it is a portion of a thermohydrogram.

There are scores of figures, many of them from experimental work, showing paired factors. The writer presented one of them 32 years ago (Shelford, 1920). Recent evidence indicates pairing of radiant energy and moisture. Figure 2 shows the population of prairie chickens in Indiana, chiefly northwest of Morocco, suggesting that sunshine and rainfall are paired in the case of the prairie chicken. At best the figures presented here are only strong suggestions. Weather data were not recorded where birds were, and it was necessary to study the storm routes. This led to choosing U. S. Weather Bureau's Peoria sunshine and Kankakee temperature and rainfall to draw the figures. Furthermore the number of years is small.

There are two or more critical periods in the annual cycle of this bird. Probably the most important is the last phase of the growth of the gonads, chiefly in April. It is evi-

dent that the combination at that time of 50 percent to 65 percent possible sunshine paired with two to three or even six and one half inches of rain was associated with the highest number of booming males in the following year. However, many things probably happen to a population in the other 11 months. What should be known is the number of eggs produced and the relative vigor of the young (Sabrosky et. al., 1933; Bailey, 1946).

If the number of males is plotted on a linear graph it is not possible to draw any conclusion as to relation to rainfall.

The second phase of the prairie chicken life cycle is concerned with incubation, during May for the majority of individuals. This does not usually appear to be a critical period from the standpoint of the physical environment and population.

The third period falls chiefly in June when most of the population is concerned with hatching and rearing of the young. This is apparently a very critical period. Temperature and rainfall appear to be paired and important. We should have the number of young birds at the end of June, but again, only the numbers of booming males of the following spring are known. Figure 3 shows the paired factor relations. The figure suggested by these data is smoother and generally better. Less

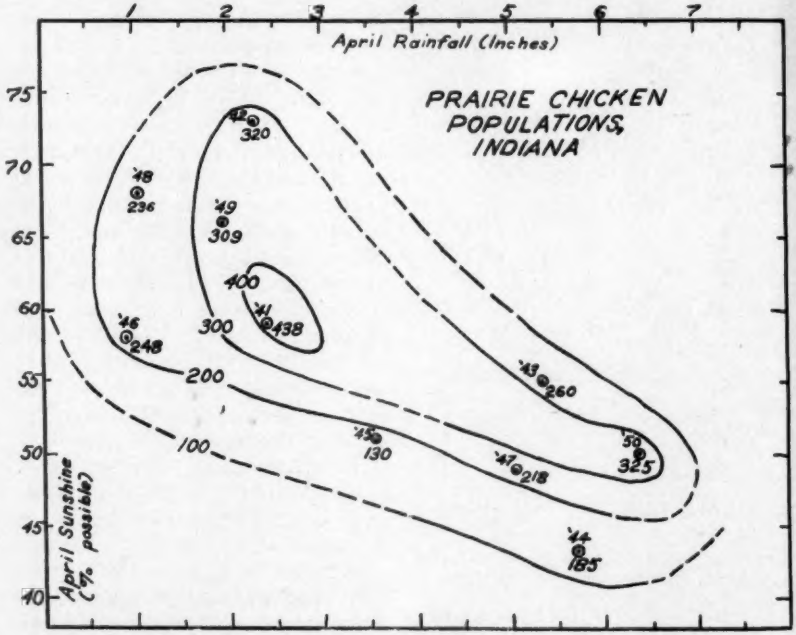

FIG. 2.—A heliohydrogram of the prairie chicken, *Tympanuchus cupido americanus* (Reichenbach), population in northwest Indiana for the sensitive period of April. Bird data (booming males in the year following) from the Ind. Cons. Dept.

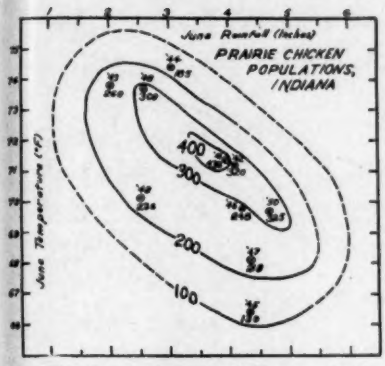

FIG. 3.—A thermohydrogram of the prairie chicken population in figure 2 for the survival-sensitive period of June; data from Indiana Cons. Dept.

happens to a population in the nine months than in the nine plus two months. The highest populations are associated with temperatures between 69° and 74°F. and rainfall of 2.5 and 4.6 inches. An inspection of these ranges shows that the entire range of population size falls within the optimum range of rainfall. The optimum range of temperature would be no better if the blanks at the right were filled.

Beginning at the end of July there is a 9-month period in which the prairie chickens, young and old, are feeding, resting, hiding, etc. The success of the group is related to the amount of cover and food, especially in winter. We have no data on the population which we have been discussing, but in Illinois the State Agriculture Department's Crop Reporting Office maintains a record of the condition of pastures which represent the gross results of the vegetative growth of plants month by month. Figure 4 shows the relation of pastures and the Hunt City, Illinois, prairie chicken population, 1935-1948. The data cover April through October. Here the largest populations came with best pasture conditions. This eight or nine months includes no critical period except for unusually severe weather. Severe food shortage may be a critical or master factor which predominates over other factors.

Larsen (1943) has referred to some internal factors as master factors. The urge to gather on the booming grounds would be an internal master factor. Furthermore, one of the two pairs of factors operating coordinately may be a master factor or at least much more important than the other one.

Ultraviolet was a master factor in the period 1924 through 1938 in the case of the quail in the entire state of Ohio and chinch bugs over a large area. In this case the short-wave radiation operated with reference to a narrow band of optimum intensity (Shelford, 1951, fig. 12, p. 169). Unfortunately neither the quail data nor the chinch bug data are so arranged that paired-factor diagrams can be drawn. In the case of the Wisconsin quail data, it was not possible to use deviation from an optimum band of ultraviolet as noted above. This may be because the critical period of gonad growth and ultraviolet sensitivity fell partly in April and partly in May, owing to the latitude. Examination of any of the paired-factor diagrams indicates the probable futility of the study of single-factor relations unless one of the factors happens to be a master factor (Marshall and Bowden, 1934).

There is little information on the size of seed crops from year to year that can be compared with animal

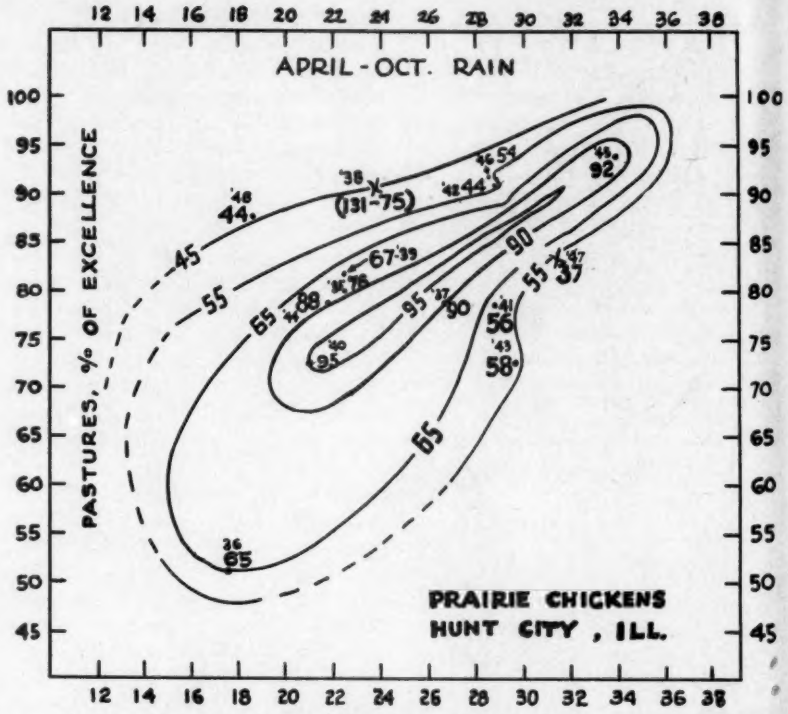

FIG. 4.—A phytohydrogram indicating food and plant cover for Hunt City prairie chickens. Bird data from the Illinois Nat. Hist. Survey. Rainfall, U. S. Weather Bur., Newton. X = discordant values, 1947 change in crops, 1938 cause unknown (possible inward migration). Calculated value, 75.

population fluctuations. In the case of cultivated plants it appears that the only paired-factor diagrams are concerned with plant diseases (Tehon, 1924, 1927). With all that is at stake it seems strange that no studies of crop production have been made by this method.

Part of the uncertainty in planning research results from the lack of weather records on the areas of population being studied. Recording rainfall gages and temperature, humidity, and sunshine recorders have been available for many years. Most require attention once a week, but with slight modification they can be adapted to fortnightly servicing. Field measurement of ultraviolet is by no means impossible, especially where electric current is available. Thirty years ago field instruments were probably in more common use than at present, probably because of the small value they appear to have from the single-factor viewpoint.

Laboratory facilities have been wanting in many cases. Ecology, wildlife management, parasitology and other subjects require outdoor

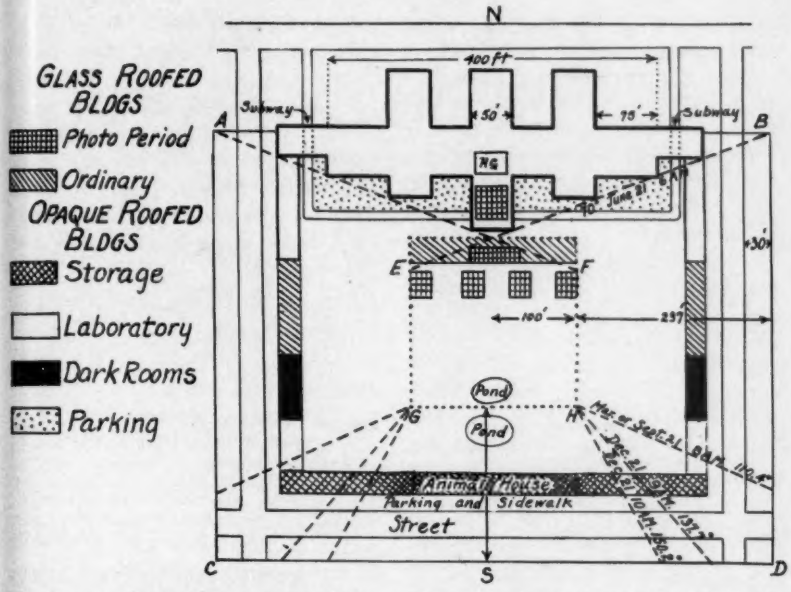

FIG. 5.—Life science building with a south yard enclosed by one-story buildings. Area E F G H, a little less than 200 feet square at 40°N., has no shadows from about an hour after sunrise to an hour before sunset when objects 70 feet high are 237 feet from its east or west border. The distance from its south border in winter is a little less. The four small green houses are so arranged that special glazing or treatment of the roof of one will not interfere with the others. The main building casts no shadows on the well-lighted area, EFGH. Its roof can provide small garden space (RG) and a glass-roofed house for summer use. This is an improvement of the plan described earlier (Shelford, 1952), based on the practices and difficulties of investigators using such facilities.

space and glass-roofed rooms. Figure 5 is a plan proposed for a life science building. For fields of research requiring outdoor space, the main building is of little concern. Only the roof features are for practical use in the growing season. The yard to the south of the main building is of critical importance. It must be surrounded by useful and necessary one-story buildings. The dark rooms make possible the drawing of plants and animals into the yard for any period of length of day. Length-of-day effects have been reported for everything from aphids to zinnias and bulls to Xanthium, but very few wild plants and animals have been studied. Facilities should be available for adding a very small amount of ultraviolet to the light under which the experimental animals are living. This calls for electrical and other facilities not available or easily used in the field. Refined measurements are needed. To make the results applicable in nature, all suggested interpretations of experiments and weather analyses must be checked out-of-doors experimentally.

One institution in each large state should provide such facilities. In

Illinois two of the state-supported institutions of higher education have turned down every suggestion for such facilities. Some of the others have a special obligation to provide such facilities; they are essential for the study of the ecological, wild-life, and general conservation problems of Illinois.

ACKNOWLEDGEMENTS

Thanks are due Wm. B. Barnes for releasing the prairie chicken data used in figures 2 and 3. This is from the files of the Indiana Department of Conservation. Similar acknowledgement is due R. E. Yeatter (1943) of the Illinois Natural History Survey for the release of the Hunt City, Illinois, prairie chicken data used in figure 4. Dr. Yeatter contributed much in other ways also. Thanks is due J. A. Ewing of the Illinois Crop Reporting Service for the pasture data.

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INHERITANCE AND FREQUENCY OF y GENE IN THE WHITE MARKED TUSSOCK MOTH

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Larvae of the white marked tussock moth, *Hemerocompa leucostigma*, were observed to have either yellow or white tussocks, dorsal paired tufts of hair. The inheritance of the color was studied to determine dominance and to calculate the frequency of the genes in the population.

The tussock moth is an excellent organism to study gene drift, mutation pressure, selection, and the effect of size of breeding population upon change of genetic constitution of the population. The female moth is flightless and grub-like in appearance, and the male is a weak flier. Upon emergence the female does not move from the remains of the pupa, and after fertilization lays her eggs around the shell of the pupa. Thus the dispersal of the moth is restricted.

During the summer of 1948 larvae were collected in Armour Square Park, Chicago, and isolated in half-pint milk bottles. The larvae were fed maple leaves and a few drops of water daily and kept in a room with a constant temperature of 20°C. The pupae from which the males emerged were smaller and usually lighter in color. There were no visible differences between pupae of females that were produced by larvae that had yellow or white tussocks.

Results of the matings are reported in table 1. It is evident that white tussock color is dominant over yellow, for in experiment D, the yellow female mated to a white male produced all white offspring in the first generation. Upon inbreeding the typical three-to-one Mendelian ratio is obtained with yellow tussock color (y) as the recessive factor. The results from the matings made in experiment A indicate that sex-linked inheritance is ruled out for this set of alleles of tussock color. If the y gene were sex-linked then a yellow male when mated to a white female should produce all yellow females in the first generation (in moths females are the heterogametic sex); however, this is not the case. The y gene is an autosomal recessive one.

Table 2 is a summary of the counts of tussock color made during three summers. In the Chicago area there are normally two generations; the caterpillars are to be seen most frequently during the middle of July and at the end of August. The instar before pupation was one counted. One can see that white tussock moths number about 70 percent, which fact is reflected in that the full common name is the "white-marked" tussock moth. By means of the Hardy-Weinberg formula

TABLE 1.—RESULTS OF MATINGS OF H. LEUCOSTIGMA

A.	White ♂ × yellow ♂	
	F_1 41 ♂ white	F_2 96 ♂ white 91 ♂ white
	44 ♂ white	32 ♂ yellow 31 ♂ yellow
	0 yellow	
B.	Yellow ♂ × yellow ♂	
	F_1 94 ♂ yellow	F_2 101 ♂ yellow
	97 ♂ yellow	107 ♂ yellow
	0 white	0 white
C.	White ♂ × white ♂	
	F_1 107 ♂ white	F_2 151 ♂ white
	101 ♂ white	163 ♂ white
	0 yellow	0 yellow
D.	Yellow ♂ × white ♂	
	F_1 84 ♂ white	F_2 89 ♂ white
	81 ♂ white	95 ♂ white
	0 yellow	32 ♂ yellow
		30 ♂ yellow
E.	White × yellow	
	F_1 74 ♂ white	
	73 ♂ white	
	76 ♂ yellow	
	72 ♂ yellow	

(1, 2) q^2TT :2q (1-q) Tt : 1-q^2tt, in which tt = homozygous recessive yellow tussock color, the percentage of population that is heterozygous for y and homozygous for Y can be calculated. The results of these calculations are presented in table 2. The frequency of gene y (t) is approximately 55 percent, but since it is recessive it is apparent in only 30 percent of the population.

The y gene did not increase or decrease significantly during 1948, 1949 and 1950. The population with reference to gene y is stable. There appears to be no selection for or against this gene or the chromosome in which it is located. This does not mean that there is no selection occurring in this organism; it means that there is no advantage or disadvantage to the organism when it contains YY or yy genes.

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TABLE 2.—FREQUENCY OF TUSSOCK COLOR IN LARVAE IN ARMOUR SQUARE PARK, CHICAGO.

Year	White	Yellow	q^2 TT: 2q (1-q) Tt:1-q^2tt			t
			YY	Yy	yy	
1948.....	721	316	20.27%	49.26%	30.47%	.552
1949.....	1352	577	20.52	49.57	29.91	.547
1950.....	963	416	20.34	49.50	30.16	.549

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RESPONSE OF GONADS OF FROG LARVAE TO CHORIONIC GONADOTROPINS AND SYNTHETIC ANDROGENS[1]

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The effects of hormones on the gonads and gonoducts of amphibians have been described numerous times during recent years. The many kinds of experimental animals and the variety of hormonal substances administered have given somewhat inconclusive results (reviews by Blair, 1946; Gallien, 1950). Administering chorionic gonadotropins to adult amphibians in tests for pregnancy in the human being has become a useful and commonplace procedure (Robbins, Parker, and Bianco, 1947; Robbins and Parker, 1948; Galli-Manini, 1948; Wiltberger and Miller, 1948). However, it is reported that administering chorionic gonadotropins to larval anurans has no apparent effect on gonads (Krichesky, 1934; Mintz, Foote and Witschi, 1945). Puckett (1939) reports that precocious development of the gonads of *Rana catesbiana* was obtained with mammalian pituitary extracts, and Blair (1946) found that chorionic gonadotropins administered to juvenile *Bufo fowleri* retarded spermatogenesis and hypertrophied the interstitial tissue of the testis and caused accelerated growth of ovocytes in the ovary.

Materials and Methods

Larvae of *Rana sphenocephala* were obtained from a mine pond in late May. The tadpoles at that time measured between 35-50 mm. total length, with an average length for 13 animals of 44.0 mm. Histological examination of gonads showed that the sex of many of the larvae could not be definitely determined as the gonads were in an immature stage (figs. 1 and 2).

A single injection of 0.025 mgs. of testosterone propionate (Perandren-Ciba)[2] was given, in sesame oil, to one group of 50 larvae (Group I). One month later a second group of 16 larvae, in which the sex had differentiated, were injected with a like amount of testosterone propionate. Larvae of this group (Group II) were selected from a reserve of control animals which had received no treatment with hormones. A third group of larvae (Group III) received oil only and served as controls.

As the animals began to metamorphose approximately two months after the experiment was started, some of each group were given two daily injections of 0.1 cc. (100 I.U.) of chorionic gonadotropic hormone ("APL"-Ayerst)[3] and were then sacrificed at the end of the second day. Some larvae received similar injections of chorionic gonadotropin

[1] Aided by grants from the General Research Fund, Southern Illinois University.

[2] The testosterone propionate was furnished through the generosity of the Ciba Pharmaceutical Company, Summit, New Jersey.

[3] The chorionic gonadotropic hormone was supplied by Ayerst, McKenna and Harrison, Rouses Point, New York.

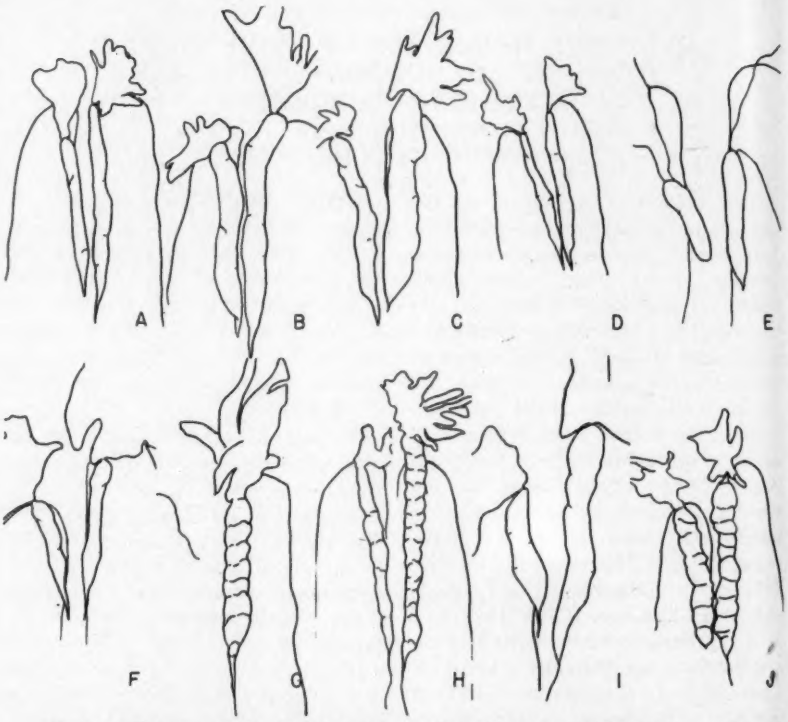


FIG. 1.—Camera lucida drawings of gonads, kidneys, and fat bodies of larval controls (A, male, B, female), gonadotropin-injected larvae (C, female; D, intersex), testosterone-treated larvae (E, F, males), testosterone- and gonadotropin-treated larvae (G, H, I, J, intersexes). X9

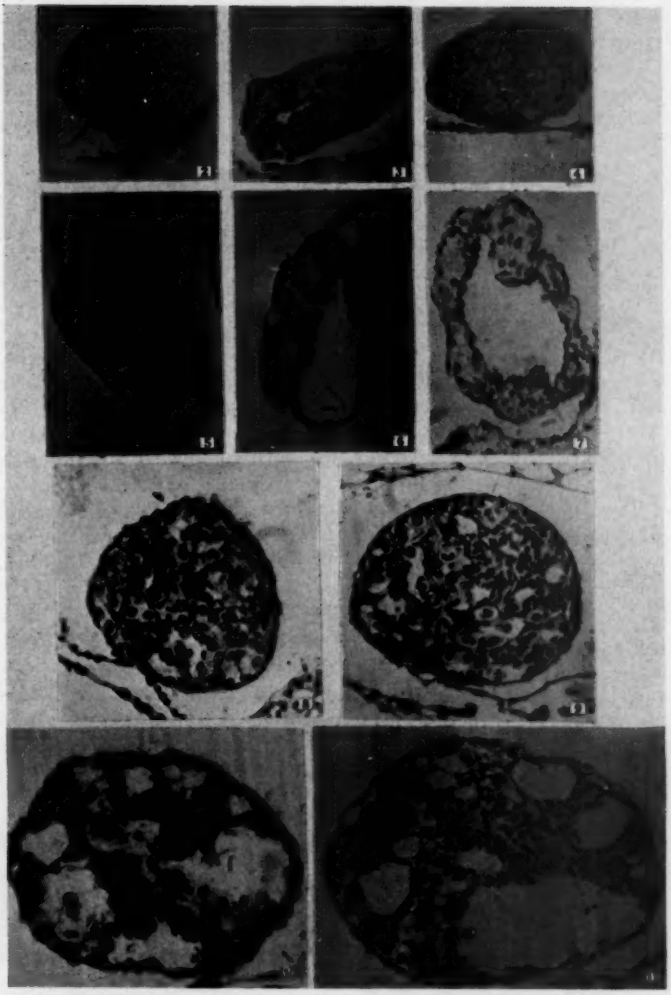
two days prior to sacrifice. It had been hoped that metamorphosed animals might be kept for longer periods of time, but the mortality in this group was so high that all animals were sacrificed soon after metamorphosis.

Larvae were kept in well-aerated aquariums in a room where the temperature varied between 15-20° C. They were fed daily on fresh lettuce leaves and dry brewer's yeast.

At the time of sacrifice the abdominal cavity was opened and the animals placed in Bouin's solution. Serial sections of 10 microns were cut and the tissues stained in Harris's hematoxylin with an eosin counterstain.

RESULTS

As would have been expected from previous investigations the animals of Group I, which received testosterone propionate, had gonads of the male type (fig. 5), as contrasted to the oil-treated controls of Group III which showed a sex distribution of 5 males and 8 females (table I). In Group II, however, where testoster-



FIGS. 2-11.—(2) Ovary of control larva at beginning of experiment. (3) Control ovary showing secondary gonad cavity one month after beginning of experiment. (4) Testis of control larva one month after beginning of experiment. (5) Testis of larva treated with testosterone propionate. (6) Intersexual gonad of larva treated with testosterone propionate and chorionic gonadotropin. (7) Ovary of control larva treated with chorionic gonadotropin. (8) Testis of metamorphosed control. (9) Testis of metamorphosed animal treated with testosterone propionate. (10) Testis of metamorphosed animal treated with chorionic gonadotropin. (11) Testis of metamorphosed animal treated with testosterone and chorionic gonadotropin. X 130.

TABLE 1.—SEX DISTRIBUTION IN CONTROL AND HORMONE TREATED ANIMALS.

Groups	Number	Treatment	Males	Females	Intersexes	Undifferentiated	Totals		
							larvae	metamorphosed	lost
Immature controls	13	none	1	2	2	8	13	0	0
I	50	T. P.	25	0	2	1	23	5	10
		T. P.[a] C. G.	2	0	10	0	11	1	
II	16	T. P.	4	3	0	0	6	1	2
		T. P. C. G.	0	4	3	0	6	1	
III	28	oil	5	8	0	0	10	3	1
		oil C. G.	0	7	7	0	11	3	

[a] T.P. Testosterone propionate.
C.G. Chorionic gonadotropin.

one injections were given after sex differentiation had already occurred there were 4 males to 3 females (table I).

The administration of chorionic gonadotropin in two injections on successive days caused marked stimulation of the interstitial tissue of the gonads of all animals treated (figs. 6 and 7). There was no apparent effect on the germ cells. The chorionic gonadotropin in stimulating the interstitial tissue caused the development, or retention, of a cavity which had the appearance of a secondary ovarial cavity. The gonads of animals which were genetic males or sex-reversed males, as a result of the testosterone treatment, and which also received chorionic gonadotropin, appear to be of an intersexual type (fig. 6). In groups which received chorionic gonadotropin the sex ratios were modified from that expected with a preponderance of intersexes or females. Instead of the expected sex ratio of 1:1 in the controls and 100 percent males following testosterone treatment very few gonads were of the male type in those animals receiving chorionic gonadotropins (table I).

Whereas the larval testes stimulated with chorionic gonadotropin assume the form of gonads with much distended ovarial sacs with germ cells surrounding the cavities (fig. 1: G, H, I, J), the testes of metamorphosed males, treated with chorionic gonadotropin, resemble the testes of control males, showing the formation of seminiferous tubules and interstitial cell stimulation (figs. 8, 9, 10, 11).

Ovaries of larvae show some effects of the chorionic gonadotropin in that the interstitial tissues are stimulated and the ovarial cavities appear to be more distended than those of controls. However, no marked differences are apparent between ovaries of metamorphosed animals treated with chorionic gonadotropins and control animals, but the small number of females prevents the drawing of any definite conclusions concerning the growth of ovocytes.

The wolffian ducts of none of the groups of animals, larval or metamorphosed, show any apparent unnatural increase in size. The mullerian ducts could not be definitely identified and, as in normal animals, are undeveloped at this stage.

Discussion

A single injection of 0.025 mgs. of synthetic male sex hormone (Perandren-Ciba) is sufficient to bring about reversal of sex from female to male if treatment is started before sex differentiation has occurred. Mintz (1948) has shown that 1 gamma per liter of aquarium water, administered to larvae of *Rana sylvatica*, from hatching to metamorphosis, is sufficient to bring about induction of male development. The amount of testosterone propionate injected into larvae in this experiment was greater than the amount used by Mintz. In the group of older larvae (Group II) treated with testosterone propionate no great modification of the ovaries was noted, but it is probable that if the amount of hormone had been increased and the experiment had been prolonged, reversal of females to males would have occurred. Mintz, Foote, and Witschi (1945) found that a total

of 4.0 mgs. of testosterone propionate in weekly injections brought about sex reversal in *Rana clamitans* larvae.

The chorionic gonadotropin used in this experiment ("APL"-Ayerst) contained a preponderance of lutenizing hormone. This preparation, as stated by the pharmaceutical company preparing it, is to be used therapeutically for the lutenizing effect to aid corpus luteum development. Therefore little effect on follicle stimulation could have been anticipated. Injections of this hormone into adult males of *Rana pipiens* in our laboratory caused the appearance of spermatozoa in the urine, as in cases of testing positive pregnancy urine. Treatment of larval forms with this hormone brought about no maturation of the germ cells; the entire effect of the hormone was on the interstitial tissues of the gonad. Krichesky (1934) reports that human pregnancy urine extracts administered over a period of 10 days had no effect on larvae of *Rana catesbiana.*

There have been few reports of the use of a combination of sex hormones and chorionic gonadotropins on anuran larvae. Puckett (1939) found precocious development of gonads of *Rana catesbiana* tadpoles with injections of mammalian pituitary extracts, as well as acceleration of the development of sex reversed gonads of larvae receiving both sex hormone and pituitary injections. Mintz, Foote, and Witschi (1945) using a variety of gonadotropic substances found no effect on the course of sex reversal of females to males in *Rana clamitans* larvae treated with testosterone propionate.

There are several factors involved in the variations in results reported by Puckett (1939), Mintz, Foote and Witschi (1945), and by the present investigator. Some of these are: 1.) different species of anurans were used, 2.) Puckett and Mintz, Foote, and Witschi began treatment with sex hormones and gonadotropins at a time when the sex of the larvae had already differentiated, whereas, in the present experiment, treatment with sex hormones began before sex differentiation was complete, 3.) in the experiments of Puckett and Mintz, Foote, and Witschi, treatment with the two types of hormones was simultaneous, whereas in the present experiment the gonadotropin was not administered until shortly before the animals were sacrificed, and after sex reversal had occurred, 4.) dosage of hormone was less in the present experiment, and 5.) apparently there was a greater proportion of follicle-stimulating hormone in the gonadotropic substances used in the earlier experiments, while here the gonadotropic hormone contained mostly lutenizing substances.

Engle (1939) states that the evidence from animal experiments indicates that human chorionic hormone is never a follicle stimulator and that in the male at ages below maturity, the uniform response is the hypertrophy and hyperplasia of the interstitial cells with the concomitant production of androgens. In this experiment with larval anurans there is a marked hypertrophy of interstitial cells of the gonad, but there is little evidence to indicate whether or not androgens were produced. No response of the gonoducts

was noted, even though synthetic androgen was administered. It may be that the wolffian ducts were not mature enough to respond to androgen stimulation even though the hormone was present or perhaps the injected androgen was in insufficient amounts to bring about a response.

On the other hand, the testes, even though stimulated with chorionic gonadotropin, may produce no androgens during the larval stage. Perhaps, if the experiment could have been prolonged the testes would have produced androgens and brought about stimulation of the gonoducts. It does seem, however, that the gonads were not producing natural androgens during the larval period of development.

Summary

1. A single injection of 0.025 mgs. of testosterone propionate administered to larvae before sex differentiation is complete brings about reversal of sex from female to male, after a period of two months.

2. A single injection of 0.025 mgs. of testosterone propionate administered to larvae after sex differentiation has occurred does not bring about reversal of sex, after a period of one month.

3. Two injections of 0.01 cc. (100 I.U.) of chorionic gonadotropic hormone just prior to the time of sacrifice cause stimulation of interstitial tissues of the gonads.

4. In larvae, the testes respond to chorionic gonadotropic hormone stimulation by the formation of a cavity in the gonad which is similar to the secondary gonad cavity of the ovary.

5. In metamorphosed animals the testes respond to chorionic gonadotropic hormone treatment by formation of seminiferous tubules and the hypertrophy of interstitial tissues.

6. Wolffian ducts are not stimulated by synthetic male sex hormones or by chorionic gonadotropic hormones. Mullerian ducts were undeveloped in animals observed.

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VARIATIONS IN WHITE BLOOD CELLS BETWEEN NORMAL AND RED LEG FROGS

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The total and differential white-cell counts of normal frog blood are known (1). The writer (2) has shown that no sex difference exists in the total white-cell count in normal frogs, but that a significant reduction occurs in this count in frogs with red leg disease (table 1). Because of the importance of white cells, a further analysis of the white-cell picture was made by statistical comparisons of the differential white-cell count in normal frogs with those in red leg disease.

Material and Methods

Rana pipiens and at times *Rana clamitans* were used. No species difference in blood picture was noted. Ninety-three normal frogs were compared to 80 animals which presented fullblown signs of red leg disease. In addition, 40 animals in the terminal stages of the condition were studied. In the early experiments an attempt was made to use only frogs which had acquired red leg in nature. Since frogs appeared to develop a natural resistance at certain seasons, the disease was produced in most cases by injections of *Pseudomonas hemophila* cultures. These were obtained from the American Type Culture Company and were maintained by alternate growth on agar plates and broth. Artificially and naturally infected animals had essentially similar blood pictures.

Recently we have used another more satisfactory method to grow red leg cultures. *Pseudomonas hemophila* is grown on a heart-brain agar slant and incubated 48 hours at 37° C. The slant is transferred every 24 hours. A virulent slant is washed with 10 cc. of physiological saline. This saline suspension is diluted 1/10 to 1/10,000 of its suspension volume. 1 cc. of each one of the dilutions is injected into frogs until a dilution which produces the disease without quickly killing the animal is obtained. Control frogs are injected with saline alone. Sterile technic is used.

The total white counts had been determined previously (2) on a hemacytometer stage. The blood for the smears was taken only from the ventricle of the heart to rule out possible differences between central and peripheral blood. The smears were stained in Wright's or Giemsa's solution and studied under oil immersion.

Only four varieties of white cells were tabulated. These included mature lymphocytes, basophiles, eosinophiles, and neutrophiles. Because of the questionable nature of monocytes and their rarity in the frog (3), these were classified as large lymphocytes and included in the lymphocyte count. This procedure has been followed elsewhere (4).

* With the technical assistance of Francis Pantelis and Harvey Pitt.

TABLE 1.—COMPARISON OF TOTAL WHITE BLOOD COUNTS BETWEEN NORMAL AND RED LEG FROGS FOR BOTH SEXES.

No. of animals	Sample mean	Deviation of sample mean	t value
Male Normal 50	16,134	1,240	3.9
Male Diseased 50	13,700	4,180	
Female Normal 50	14,161	3,091	2.6
Female Diseased 50	12,300	3,860	

The results were subjected to statistical analysis, using the Student t equation. The level of significance was chosen as 2.0.

EXPERIMENTAL DATA

The total white count had been found to be reduced significantly in disease. The possibility of sex difference in both normal and diseased frogs had been considered but no such difference was observed; the t value between normal males and females equals 0.13 and that between diseased animals equals 0.07. These facts are summarized or derived from data in table 1.

In the differential count the data were collected without regard to sex because of the absence of sex difference as noted above. In the acute stage, a statistically significant rise in lymphocytes was observed. This was offset, however, by a significant decrease in the number of circulating neutrophiles together with a slight decrease in eosinophiles. Except for the terminal stages there was no change in basophiles. These observations are summarized in table 2.

To check for changes in terminal stages of the infection, differential counts were done on 40 moribund frogs. The mean percentages and standard deviations were: lymphocytes, 87.59 ± 5.56; neutrophiles, 5.98 ± 3.85; basophiles, 4.34 ± 1.92; and eosinophiles, 2.08 ± 1.74. The granulocytes have been depressed to an even greater degree.

Some observers (5) have stated that a marked leukocytosis occurs in human beings under conditions of cold and pregnancy. Because the frogs were generally stored for one to three weeks in a refrigerator and also because gravid females were occasionally used, control experiments with non-gravid females kept at room temperature were run to see whether such conditions had any noticeable effect on the experimental data. Neither the total nor the differential counts were appreciably altered by

TABLE 2.—COMPARISON OF DIFFERENTIAL WHITE COUNTS BETWEEN NORMAL AND RED LEG INFECTED FROGS.

Variety of white cells	Number of animals	Mean percentage	Standard deviation of mean	t value
Basophiles	Normal 93	6.74	3.35	0.60
	Diseased 80	7.14	2.73	
Neutrophiles	Normal 93	20.75	10.60	6.54
	Diseased 80	7.36	4.11	
Eosinophiles	Normal 93	8.03	5.98	1.93
	Diseased 80	6.30	2.23	
Lymphocytes	Normal 93	64.48	10.63	7.12
	Diseased 80	79.20	4.91	

the environmental temperature or by the gravid state of the animal.

The changes in the blood picture are characteristic in red leg disease. Figure 1 shows a bacteremia with attendant vacuolization of infected red cells and a predominance of lymphocytes which everywhere crowd out the granulocytes. Figure 2 in contrast shows a haemogregarine infection, but most of the red cells appear normal and the granulocyte line was found not to be depressed.

An explanation of the decrease in the total leucocyte count was sought in the findings in the differential counts. This was done (table 3) by converting the mean percentage of each variety of white cell into the numbers per cubic mm. in both normal and diseased frogs and comparing the changes in these numbers between health and disease.

The analysis of results in the acute phase show that in spite of a relative lymphocytosis (for every 100 cells) as seen on smears, there is no substantial increase per cubic mm. (except for terminal stages) because of a large drop in the total number of circulating cells. On the other hand, in the acute phase, the neutrophiles decrease greatly and the eosinophiles mildly. The basophiles may not significantly change. In the terminal stages all granulocytes decrease more sharply. The neutropenia in particular more than offsets any lymphocytosis, which apparently explains the drop in the total white count.

DISCUSSION

Red leg disease is produced by *Pseudomonas hemophila* and is infectious for several species. The characteristic effect is a hemorrhagic septicemia (6). The writer has described in this paper and elsewhere (2) some of the quantitative hematologic changes involved. It is important to know the nature of this usually fatal disease as an aid to control in an animal so extensively used as the frog.

TABLE 3.—CONVERSION OF MEAN PERCENTAGES OF WHITE CELLS INTO NUMBERS PER C. MM. IN NORMAL AND DISEASED FROGS.

Normal frogs				Diseased frogs				
Total count per c. mm. (average of all males and females)	Differential count Mean percentage		Number in total count per c. mm.	Total count per c. mm. (average of all males and females)	Differential count Mean percentage		Number in total count per c. mm.	
						Acute stage	Terminal stage	Acute stage	Terminal stage
15,148	Lymphocyte	64.48	9767.43	13,000	Lymphocyte	79.20	87.59	10,296.00	11,386.70
	Neutrophile	20.75	3143.21		Neutrophile	7.36	5.98	956.80	777.40
	Eosinophile	8.03	1216.38		Eosinophile	6.30	2.08	829.00	270.40
	Basophile	6.74	1020.96		Basophile	7.14	4.34	928.20	564.20

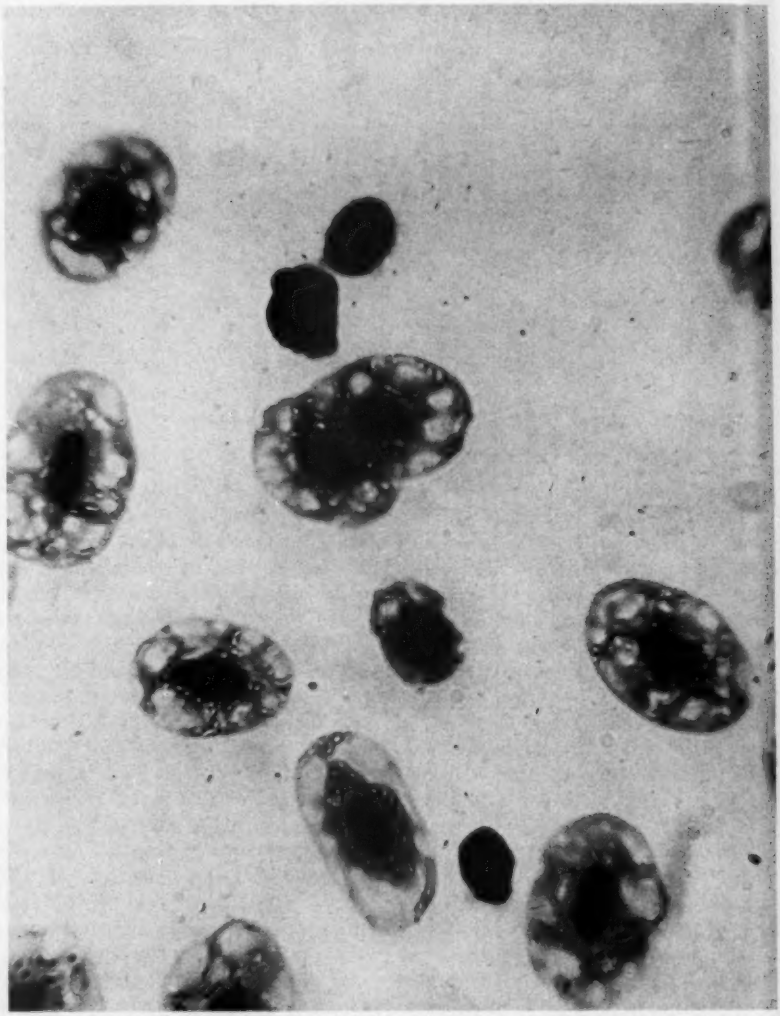

FIG. 1.—Blood smear treated with Wright's stain showing Pseudomonas invasion with vacuolization of red cells and predominance of lymphocytes. A typical field. About x 600.

The differential white count in the infectious diseases among animals and man varies with the specific disease. Leucocyte changes are among the most conspicuous of the pathological signs of infection and a differential count can help determine the nature of the infection. In red

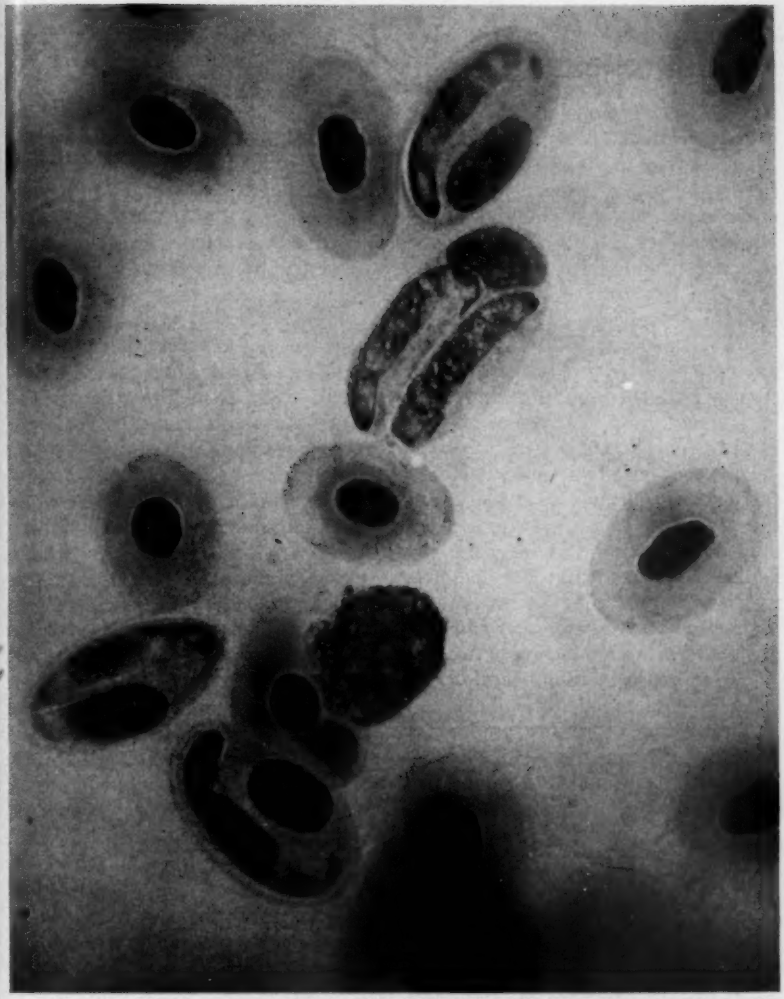

FIG. 2.—Blood smear treated with Wright's stain showing infection with Haemogregarina sp. Most red cells appear normal and the white count is not markedly changed. About x 600.

leg disease there appears to be a leucopenia, involving the granulocytes and predominantly the neutrophiles. In any human disease where the effects of the infection are overwhelming there may similarly occur a leucopenia which is predominantly a neutropenia (7). In the diseased frog a sharp relative increase in lymphocytes occurs, even

when the disease is in the early stages, and it becomes more marked in the terminal stages. This is not unusual since there are many instances of lymphocytosis during acute infections (8).

In the frog the lymphocyte is said to be the usual progenitor of all other cells in the peripheral blood. Directly after hibernation the blood cells are produced in the bone marrow, and later in the spleen and intestinal submucosa. These sites of blood cell production are apparently not depressed in function since the stem cell has been found in this study to increase in percentage and perhaps in concentration at all times of year in response to Pseudomonas infection. Its derivatives, the granulocytes, tend to be destroyed, probably in attacking the invading organism. The resulting leucopenia is of grave import, since it indicates a depression of vital function which is always fatal within our observations.

The increase in lymphocytic stem cells appears to be a compensation for destruction of adult granulocytes and may represent a "shift to the left." Transitional or immature cells not found in healthy animals appear. This perhaps indicates regeneration in hematopoietic areas.

Normal values for the types of white cells, although given in the literature (1), were redetermined in this paper because a more immediate set of standards was required for statistical comparison with values in disease under comparable conditions. Also, our results are based upon a larger sample than that used elsewhere to obtain normal values.

Summary

Normal values for the types of white cells in frog blood were determined. The total white-cell count of frogs was significantly reduced in red leg disease. Differential counts showed a significant decrease in neutrophiles and a slight drop in eosinophiles with a concomitantly significant rise in the number of lymphocytes. In the acute stage there was no change in basophiles. The suppression of all granulocytes became more evident in terminal stages of the disease. Conversion of cell numbers from percentages to numbers per cubic mm. indicated that the granulocytopenia more than compensated for any increase in lymphocytes, thus apparently explaining the observed total leucopenia.

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NEOTROPICAL EXODONT BRACONIDAE (HYMENOPTERA)

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Several years ago while looking at the undetermined braconids in the collection of Dr. Henry K. Townes, I noticed the largest and most handsome specimen of alysiine I had ever seen. It was one to rival those pictured by Cameron in the Biologia Centrali-Americana. In Szépligeti's 1904 key this specimen runs to the genus *Mesocrina* Foerster, but I prefer to assign it, temporarily at least, to *Alysia* Latreille.

Alysia townesi sp. nov.

This species apparently is related to *Alysia pulchripennis* Cameron and *A. xanthoptera* Cameron. It resembles the former in the color pattern of the front wings, but differs in having a light-colored thorax. It resembles *xanthoptera* in general body coloring, but differs in the color pattern of the wings.

Color of thorax and abdomen testaceous; head, antennae and hind coxae dark brown, almost black; mandibles almost white; palps pale testaceous; front wings testaceous, tipped with brown, and a brown streak from stigma to posterior edge; hind wings testaceous with some brown along apical third of anterior margin; eyes, pronotum and middle coxae brown; last segment of front tarsi, last two segments of middle tarsi, all segments of hind tarsi dark brown; hind femora and tibiae dark brown except near the joints; remaining portions of legs testaceous.

Female.—Length, exclusive of antennae and ovipositor, about 9 mm. Head, as seen from above, transverse, deeply concave behind, more or less impunctate and shining above; scattered long hairs on occiput; long yellowish hair abundant between eyes and antennae, on frons, clypeus and mandibles; eyes ovate; clypeus, frons and area between eyes and antennae finely pitted; frons with a median elevation that is widest at upper end; clypeus rounded and projecting; antennae 103- to 104-segmented, nearly twice as long as body.

Mesonotum shining, with scattered long hairs; notaulices lacking except for two shallow depressions at anterior end; mesopleuron and mesosternum shining and almost smooth, hair mostly confined to latter; propodeum rather smooth, hairy, with median carina which divides at posterior end and runs to bases of hind coxae; spiracles not projecting, enclosed in the upper end of a raised figure 8; wing venation almost as illustrated by Cameron (1887, pl. 16, fig. 23) for *xanthoptera*.

Petiole about 1.5 times as long as wide at apex, with median carina back as far as spiracles which are projecting; abdomen smooth and shining, with sparse hair, somewhat

compressed, about as long as head plus thorax; ovipositor missing from holotype.

Male.—Unknown.

Holotype, female.—Abitagua, Baños, Ecuador, Sept. 21, 1937, 1200 m., W. Clarke-MacIntyre. Deposited in the collection of Dr. Henry K. Townes, Raleigh, N. C.

This species is named in honor of Dr. Townes in appreciation of many courtesies.

Alysia townesi is the thirty-sixth exodont braconid to be reported from the Americas south of the United States. A catalog of these forms is appended. The eventual generic assignment of some species (for example, Spinola's) is problematical. Citations in Dalla Torre (1898) and Szépligeti (1904) are not listed in the catalog unless pertinent. The term neotropical is used here to include all of Mexico.

CATALOG OF PREVIOUSLY DESCRIBED NEOTROPICAL EXODONT BRACONIDAE

SUBFAMILY *DACNUSINAE*

GENUS *Chorebus* Haliday

nigrifrons (Brèthes), n. comb. Chile (Los Vilos).

Gyrocampa nigrifrons Brèthes, 1921. An. de Zool. Aplicada 8: 6. Female.

pallidinervis (Brèthes), n. comb. Argentina (Buenos Aires).

Gyrocampa pallidinervis Brèthes, 1913. Buenos Aires Mus. Nac. de Hist. Nat. An. 24: 42. Female.

GENUS *Dacnusa* Haliday

diluta Spinola. Chile.

Dacnusa diluta Spinola, 1851. *In* Gay: Hist. Fis. Chile, Zool. 6: 548. Female.

tripartita Spinola. Chile (Valdivia).

Dacnusa tripartita Spinola, 1851 *In* Gay: Hist. Fis. Chile, Zool. 6: 549. Male.

SUBFAMILY *ALYSIINAE*

GENUS *Aphaereta* Foerster

apicalis Ashmead. Grenada (Mount Gay Estate), W. I., Cuba. Host: An undetermined tachinid parasite of the arrowroot leafroller, *Calpodes ethlius.*

Aphaereta apicalis Ashmead, 1895. Zool. Soc. London Proc. 1895: 786. Female.

Aphaerete (!) *apicalis* Dalla Torre, 1898. Cat. Hym. 4: 41.

Aphaereta apicalis Brues, 1908. *In* Washburn, Minn. State Ent. Rept. 12: 196.

Aphaereta apicalis Myers, 1931. Bull. Ent. Res. 22: 275.

Aphaereta apicalis Myers, 1935. Bull. Ent. Res. 26: 242.

laeviuscula (Spinola). Chile (Valdivia).

Alysia laeviuscula Spinola, 1851. *In* Gay: Hist. Fis. Chile, Zool. 6: 545. Male, female.

Alysia leviuscula Dalla Torre, 1898. Cat. Hym. 4: 46. Emend.

Alysia leviuscula (!) Szépligeti, 1904. *In* Wytsman, Gen. Ins., fasc. 22: 209.

Aphaereta laeviuscula Brèthes, 1916. Rev. Chilena de Hist. Nat. 20: 88.

melanura Schrottky. Argentina (Prov. Buenos Aires).

Aphaerete (!) *melanura* Schrottky 1902. Buenos Aires Mus. Nac. de Hist. Nat. An. 8: 104. Female(?).

Aphaereta melanura Schrottky, 1913. Soc. Cient. Argentina An. 75: 129.

testaceipes Brèthes. Argentina (Buenos Aires and Punta Lara).

Aphaereta testaceipes Brèthes, 1913. Buenos Aires Mus. Nac. de Hist. Nat. An. 24: 42. Male, female.

Aphaereta testaceipalpis (!) Brèthes, 1913. *Ibid.*, p. 165.

[Thompson (Cat. Paras. and Pred. Ins. Pests, sec. 1 (2): 40, 1943) quotes Myers (Empire Market. Bd. Grey Book 42, 1931) as having reared *Aphaereta* sp. from *Lixophaga diatraeae* Towns., a tachinid parasite of *Diatraea* spp. which bore in sugar cane in Cuba. (See Rev. Appl. Ent. A19: 627.)]

GENUS *Syncrasis* Foerster

flavifrons Ashmead. Grenada (Mount Gay Estate), W. I.

Syncrasis flavifrons Ashmead, 1895. Zool. Soc. London, Proc. 1895: 786. Male.

GENUS *Hoplitalysia* Ashmead

muelleri Schulz. Brazil (Santos, São Paulo).

Hoplitalysia muelleri Schulz, 1912. Zool. Anz. 39: 74. Male.

GENUS *Idiasta* Foerster

nigripennis Brues. Brazil (Abuná, Rio Madeira).

Idiasta nigripennis Brues, 1912. Ent. Soc. Am. Ann. 5: 227. Male.

GENUS *Cratospila* Foerster

testacea Szépligeti. Mexico (Las Tres Marias Ids.; ? San Juanito I.).

Cratospila testacea Szépligeti, 1902. Budapest Magyar Nemzeti Muz. Természet. Füzetek 25: 84. Male.

Cratospila testacea Schrottky, 1913. Soc. Cient. Argentina An. 75: 129.

GENUS *Alysia* Latreille

analis Cresson. Cuba, Porto Rico.

Alysia analis Cresson, 1865. Ent. Soc. Phila. Proc. 4: 88. Male.

Alysia analis Riley, 1894. Linn. Soc. London Jour. Zool. 25: 58.

Alysia analis Wolcott, 1923. Puerto Rico Univ. Jour. Agr. 7: 69.

Alysia analis Leonard, 1933. Puerto Rico Univ. Jour. Agr. 17: 104.

Alysia analis Wolcott, 1936. Puerto Rico Univ. Jour. Agr. 20: 509.

astarte Haliday. St. Vincent, W. I.

Alysia (Alysia) Astarte Haliday, 1838. Ent. Mag. 5: 229. Male, female.

Alysia astarte Stelfox, 1941. Roy. Irish Acad. Proc. 47B: 13.

bugabensis Cameron. Panama (Bugaba).

Alysia bugabensis Cameron, 1887. Biol. Centr.-Amer., Hym. 1: 415. Male.

carinata (Szépligeti). Brazil (Blumenau).

Goniarcha carinata Szépligeti, 1902. Budapest Magyar Nemzeti Muz. Természet. Füzetek 25: 84. Female.

Alysia carinata Szépligeti, 1904. *In* Wytsman, Gen. Ins., fasc. 22: 209.

cayennensis Spinola. French Guiana.

Alysia Cayennensis Spinola, 1840. Soc. Ent. de France Ann. 9: 196. Female.

championi Cameron. Mexico (Orizaba).

Alysia championi Cameron, 1887. Biol. Centr.-Amer., Hym. 1: 414. Male.

Alysia championii Dalla Torre, 1898. Cat. Hym. 4: 45. Emend.

chiriquensis Cameron. Panama (Volcan de Chiriqui).

Alysia chiriquensis Cameron, 1887. Biol. Centr.-Amer., Hym. 1: 416. Female.

chontalensis Cameron. Nicaragua (Chontales).

Alysia chontalensis Cameron, 1887. Biol. Centr.-Amer., Hym. 1: 416. Female.

erythrogaster Cameron. Panama (Volcan de Chiriqui).

Alysia erythrogaster Cameron, 1887. Biol. Centr.-Amer., Hym. 1: 414. Male, female.

longicornis Cameron. Panama (Volcan de Chiriqui).

Alysia longicornis Cameron, 1887. Biol. Centr.-Amer., Hym. 1: 414. Male, female.

macrostigma Spinola. Chile ("De las provincias centrales.").

Alysia macrostigma Spinola, 1851. *In* Gay: Hist. Fis. Chile, Zool. 6: 544. Male.

melanocephala Cameron. Panama (Volcan de Chiriqui).

Alysia melanocephala Cameron, 1887. Biol. Centr.-Amer., Hym. 1: 415. Male, female.

nemostigma Spinola. Chile (Valdivia).

Alysia nemostigma Spinola, 1851. *In* Gay: Hist. Fis. Chile, Zool. 6: 546. Female.

Alysia monostigma (!) Szépligeti, 1904. *In* Wytsman, Gen. Ins., fasc. 22: 209.

nigriceps Cresson. Cuba.

Alysia nigriceps Cresson, 1865. Ent. Soc. Phila. Proc. 4: 87. Male.

pulchella Spinola. Chile (Valdivia).

Alysia pulchella Spinola, 1851. *In* Gay: Hist. Fis. Chile, Zool. 6: 547. Male (?).

pulchripennis Cameron. Panama (Volcan de Chiriqui).

Alysia pulchripennis Cameron, 1887. Biol. Centr.-Amer., Hym. 1: 413. Male.

ridibunda Say. U. S. A., Canada, Porto Rico, ? Mexico. Host: Blowfly larvae. According to Crawford, the record of this species having been reared from *Anastrepha ludens* Lw. in Mexico is incorrect.

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THE EFFECTS OF SOME DETERGENTS ON THE DEVELOPMENTAL STAGES OF HORSE STRONGYLES (NEMATODA)

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During the past several years a search for possible anthelmintics has been carried out in our laboratory, using the developmental stages of horse strongyles. The technic has been described by Levine (1950). By its use, several compounds were discovered which, when mixed with horse feces, killed the parasites developing in the feces, or at least prevented the development of larvae. In order to learn which stages these compounds affected, a study was begun on eggs and larvae that had been separated from feces and washed clean. Because some of the compounds were not water-soluble, detergents were added to disperse them. It was then observed that the detergents themselves were toxic. The present paper reports the effects of two detergents, Triton NE and Tergitol 7, on the developmental stages of horse strongyles in water.

Materials and Methods

The strongyle eggs and larvae used in this study were obtained from feces from horses on the University of Illinois farm. The strongyles of horses belong to the nematode family Strongylidae. Three species of the genus *Strongylus* are known as large strongyles. McIntosh (1951) lists 34 species of 7 genera of small strongyles. Most of these are quite similar both morphologically and biologically, and the adults can be differentiated only with difficulty. The eggs and young larvae of most species cannot be differentiated.

Four stages of the strongyle life cycle occur in manure. The egg contains only a few cells when passed, but embryonates rapidly. A first-stage larva hatches after about a day and feeds on bacteria and other material in the feces. It molts in another day to the second-stage larva, which also feeds on bacteria. After two to four days it molts to the third-stage, infective larva. This larva does not feed; it retains the cast skin of the second-stage larva as a sheath which protects it against desiccation and chemical agents.

The eggs used in this study were obtained from fresh feces by flotation with saturated sodium chloride solution. They were placed in a Bureau of Plant Industry (BPI) watch glass 1 inch in diameter, and washed five times with tap water. They were then picked out with a micropipette, placed in another BPI watch glass, and 0.6 ml. of the test solution was added. The watch glass was covered with a round coverslip and sealed with white petrolatum. Since the capacity of these watch glasses

TABLE 1.—EFFECT OF TRITON NE ON WASHED HORSE STRONGYLE EGGS.

	Percent Triton	No. tests	No. eggs per test	Results		
					1 day	3 days
Percent eggs embryonated.....	0.5	8	14.5	Mean	76	78[b]
				σ	12.8	12.8
	Control	8	13.5	Mean	88	90[b]
				σ	9.4	5.8
Percent eggs hatched.....	0.5	8	14.5	Mean	23[a]	72
				σ	13.4	18.9
	Control	8	13.5	Mean	65[a]	87
				σ	26.7	9.5

a Difference significant at 1% level.
b Difference significant at 5% level.

is about 1 ml., oxygen for development was obtained from the 0.4 ml. of air remaining under the coverslip.

The larvae were obtained from feces which was incubated at room temperature. First-stage larvae were obtained after incubation for 1 day, second stage larvae after incubation for 2 days, and third stage larvae after incubation for 6 days. The technic of incubation was that described by Levine (1950). A cheesecloth bag containing 4 gm. feces was suspended in a 2 oz. wide-mouth glass bottle, which was then placed in a dark cupboard for the proper number of days. The larvae were collected by a modification of the Baermann technic.

After incubation, the bag containing feces was placed in a small funnel to which a piece of rubber tubing closed by a pinchclamp had been attached. Warm water was added to cover half the bag, and the preparation was allowed to stand for two hours. The water was then drained into a centrifuge tube, centrifuged for 5 minutes at 1900 r.p.m., and 0.5 ml. was removed from the bottom of the centrifuge tube with a pipette and placed in a Syracuse watch glass. This water contained most of the larvae. They were washed by adding 5 ml. of tap water and mixing. The larvae were then picked out with a micropipette, transferred to 0.6 ml. of water in a BPI watch glass and mixed again. In setting up the tests, the larvae were again picked out with a micropipette, transferred to another BPI watch glass, 0.6 ml. of the test solution was added, and the preparations were sealed with a coverslip as described above.

The eggs and larvae were observed daily. Eggs were considered dead if, after failing to embryonate, they began to disintegrate. Several criteria were used to determine whether the larvae were alive. Dead larvae lay motionless and straight or only slightly curved, they were darker than live ones, and their internal structures became progressively less distinct and finally disintegrated.

The effects of Triton NE and

TABLE 2.—EFFECT OF TRITON NE ON WASHED HORSE STRONGYLE LARVAE.

	Percent Triton	No. tests	No. larvae per test	Percent larvae alive			
					1 day	2 days	3 days
1st stage larvae.....	0.5	6[b]	13.5	Mean	77	41[a]	32[a]
				σ	31.1	29.6	21.3
	Control	6[b]	12.2	Mean	99	93[a]	95[a]
				σ	2.6	5.7	3.4
2nd stage larvae.....	0.5	4	13.5	Mean	83	87	57
				σ	13.7	10.8	27.9
	Control	4	13.8	Mean	96	96	85
				σ	3.5	3.5	11.7
3rd stage larvae.....	0.5	6	16.0	Mean	100	98	95
				σ	0	3.3	3.0
	Control	6	15.7	Mean	99	98	94
				σ	3.0	3.5	6.2

a Difference significant at 1% level.
b Only 4 tests were carried to 3 days.

Tergitol 7 were determined against eggs and larvae in the first, second, and third stages. Triton NE is manufactured by Rohm and Haas Co. It is a 33% aqueous solution of the monoisoctyl phenyl ether of polyethylene glycol, which has an average molecular weight of 633. Tergitol 7 is manufactured by Carbide and Carbon Chemicals Co. It contains 25% of the sodium sulfate derivative of 3,9-diethyltridecanol-6, 15% of the mono butyl ether of diethylene glycol as a coupling agent, and 5% of a mixture of sodium sulfate and sodium chloride, all dissolved in water. The first compound is the active detergent.

RESULTS

The effects of 0.5% Triton NE on horse strongyle eggs are given in table 1. This concentration of Triton NE is equivalent to 263×10^{-5} M. active ingredient. There was no significant difference in embryonation between the treated and control eggs after one day, but after three days 78% of the treated eggs had embryonated, as against 90% of the controls. Since the unembryonated eggs later died, this difference represents a 13% kill. It was significant at the 5% level.

Egg hatching was slowed down but not prevented. After one day only 23% of the treated eggs had hatched, as against 65% of the controls. However, after three days there was no significant difference in hatching percentages.

The effects of 0.5% Triton NE on the larvae are given in table 2. The compound killed first-stage larvae slowly. It had no significant effect after one day, but after two days 41% of the larvae were alive as against 93% of the controls, and after three days 32% of the treated larvae and 95% of the controls were

TABLE 3.—EFFECT OF TERGITOL 7 ON WASHED HORSE STRONGYLE EGGS.

	Percent Tergitol	No. tests	No. eggs per test	Results		
					1 day	3 days
Percent eggs embryonated.....	0.1	3	22.3	Mean	0[a]	1[a]
				♀	0	2.4
	Control	2	19.5	Mean	85[a]	87[a]
				♀	3.0	6.0
	0.01	3	20.0	Mean	83[a]	83[a]
				♀	1.0	1.0
	Control	2	19.5	Mean	97[a]	100[a]
				♀	1.0	0
Percent eggs hatched.....	0.1	3	22.3	Mean	0	0[a]
				♀	0	0
	Control	2	19.5	Mean	3	85[a]
				♀	2.6	8.5
	0.01	3	20.0	Mean	0	42[a]
				♀	0	1.7
	Control	2	19.5	Mean	0	97[a]
				♀	0	3.0

a Difference significant at 1% level.

alive. Thus the compound produced a 56% kill after two days and a 66% kill after three days. It had no significant effect on second- and third-stage larvae.

The effects of Tergitol 7 on the eggs are given in table 3. A concentration of 0.1% Tergitol 7 is equivalent to 70 x 10^{-5} M. of the sodium sulfate derivative of 3,9-diethyltridecanol-6, while a concentration of 0.01% is equivalent to 7 x 10^{-5} M. Egg embryonation was almost completely prevented by 0.1% Tergitol 7. No eggs had embryonated after one day, and only 1% had embryonated after three days. The unembryonated eggs died. A concentration of 0.01% was made less effective, allowing 83% to embryonate.

Egg hatching was also affected. No eggs treated with 0.1% Tergitol 7 hatched. Only 42% of the eggs treated with 0.01% Tergitol 7 hatched; of the 83% of eggs which had embryonated after three days, only 51% hatched. The larvae in the remainder died before they could get out of the eggshell.

The effects of Tergitol 7 on the larvae are given in table 4. The first-stage larvae, the most sensitive, were all killed in one day by 0.01% of the detergent. All second stage larvae were killed in one day by 0.1% Tergitol 7. There was no significant difference (at the 5% level) between the second stage larvae treated with 0.01% Tergitol 7 and the controls after one day, but after two days only 9% and after three days only 1% of the treated larvae remained alive. Taking into account the mortality in the controls, these

TABLE 4.—EFFECT OF TERGITOL 7 ON WASHED HORSE STRONGYLE LARVAE.

	Percent Tergitol	No. tests	No. larvae per test	Percent larvae alive			
					1 day	2 days	3 days
1st stage larvae.....	0.1	3	20.0	Mean	0[a]		
				±	0		
	Control	2	15.0	Mean	93[a]		
				±	7.0		
	0.01	3	22.0	Mean	0[a]		
				±	0		
	Control	2	21.5	Mean	98[a]		
				±	2.5		
2nd stage larvae.....	0.1	3	20.0	Mean	0[a]		
				±	0		
	Control	2	20.0	Mean	100[a]		
				±	0		
	0.01	3	26.7	Mean	81	9[a]	1[a]
				±	2.2	4.2	1.9
	Control	2	26.5	Mean	96	96[a]	94[a]
				±	4.5	4.5	3.0
3rd stage larvae.....	0.1	3	23.3	Mean	6[a]	0[a]	
				±	3.6	0	
	Control	2	26.5	Mean	100[a]	100[a]	
				±	0	0	
	0.01	3	23.3	Mean	100	100	100
				±	0	0	0
	Control	2	19.0	Mean	97	97	97
				±	2.5	2.5	2.5

a Difference significant at the 1% level.

figures represent 89% and 99% kills, respectively. The third-stage larvae were much more resistant than those in the first two stages. They were not affected by 0.01% Tergitol 7, but 0.1% of the compound killed 94% in one day and 100% in two days.

DISCUSSION

Tergitol 7 was much more toxic for horse strongyle developmental stages than Triton NE. The two detergents are of different types, Triton being non-ionic, and the active detergent ingredient of Tergitol being anionic. However, further tests will be necessary to determine whether the toxic effect of the Tergitol is due to the sodium sulfate derivative of 3,9-diethyltrideканol-6, to the mono butyl ether of diethylene glycol, which is non-ionic, or to both.

Jaskoski (1950, 1951) has studied the effects of anionic detergents on the eggs of the common pig roundworm, *Ascaris lumbricoides*. He found that 5.0% Duponol 80, Aresklene 400, Areskap 100 and Aresket 375 inhibited cleavage.

The present study was carried out

on washed eggs and larvae. Further work would be desirable to determine whether Tergitol 7 retains its activity in feces and in soil.

Summary

In a study of the effects of detergents on washed eggs and larvae of the small strongyles of horses, 0.5% Triton NE was found to kill 13% of the eggs and to slow down the hatching of the remainder. It killed 56% of first stage larvae after two days exposure, and 66% after three days, but had no significant effect on second- and third-stage larvae.

Egg embryonation was almost completely prevented by 0.1% Tergitol 7, and significantly decreased by 0.01% of the detergent. No eggs hatched in 0.1%, and 51% of the embryonated eggs hatched in 0.01% of the detergent. All first-stage larvae were killed in one day by 0.01% Tergitol 7. All second-stage larvae were killed in one day by 0.1% of this detergent; 0.01% did not affect them significantly in one day, but killed 89% and 99% after two and three days, respectively. Ninety-four percent of third stage larvae were killed by 0.1% Tergitol 7 in one day, and 100% in two days; 0.01% did not harm them.

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TWO NEW SPECIES OF PSEUDOSCORPIONS FROM ILLINOIS

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Since the publication of my monographic account of the pseudoscorpions of Illinois (Hoff, 1949), I have had the opportunity to examine additional collections from the state, among them two undescribed species of the monosphyronid family Cheiridiidae. These two species, one in the genus *Cheiridium* Menge and the other in the genus *Apocheiridium* Chamberlin, are described in the present paper.

The two pseudoscorpion species described here may be keyed to family by the use of keys in my "Pseudoscorpions of Illinois" or by those given by Chamberlin (1931) or by Beier (1932). In using keys in any one of these publications, however, one must keep in mind that a venom apparatus is now known to occur in both chelal fingers in at least some species of Cheiridiidae, and separation of the Cheiridiidae from the Sternophoridae can no longer be made on the basis of a venom apparatus in only the fixed finger of the Cheiridiidae. The two additional genera reported here for Illinois may be separated by the diagnostic summaries given in this paper or by the use of keys given by Chamberlin (1931) and Beier (1932).

Type specimens of the species described here have been deposited in the collections of the Illinois Natural History Survey and in the author's collections.

GENUS *Cheiridium* Menge

Cheiridium Menge, 1855, N. Schr. Naturf. Gesell. Danzig, vol. 5, no. 2, p. 36.

Cheiridium Chamberlin, 1924, Pan-Pac. Ent., vol. 1, p. 37.

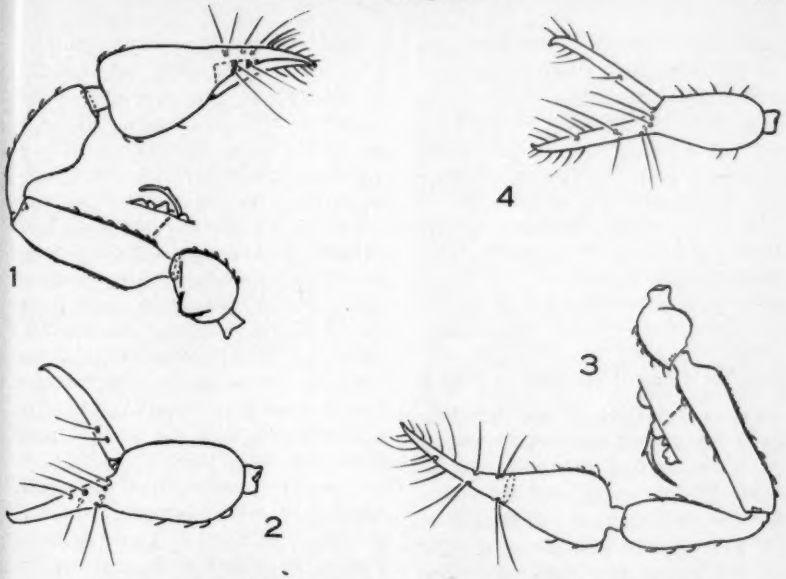
Cheiridium Beier, 1932, Das Tierreich, vol. 58, p. 7.

Species of this genus may be recognized by a combination of the following characters: humeral angle of the carapace pronounced, ten tergites visible in dorsal view, heavy granulations typically dotted-reticulate in nature, and movable chelal finger with two tactile setae. At the present time, the genus contains *C. museorum* (Leach, 1817) from Europe and North Africa, *C. simulacrum* Chamberlin, 1938, from Hawaii, *C. minor* Chamberlin, 1938, from China, and *C. insperatum* Hoff and Clawson, 1952, from Utah. In addition, a fossil form, *C. hartmanni* Menge, is known from Baltic amber.

Genotype: *Chelifer museorum* Leach, 1817.

Cheiridium firmum, new species
(Figs. 1 and 2)

Female: Description based on the female holotype and ten female paratypes; measurements given for the holotype are followed in many instances in parentheses by the ranges of measurements for all eleven females. Body robust; virtually all parts of the animal a golden



FIGS. 1 and 2.—*Cheiridium firmum*, new species, female holotype. FIG. 1.—Dorsal view of palpus. FIG. 2.—Lateral view of chela. FIGS. 3 and 4.—*Apocheiridium stannardi*, new species, female holotype. FIG. 3.—Dorsal view of palpus. FIG. 4.—Lateral view of chela.

yellow; surface sculpturing strongly marked, especially on the carapace, the tergites, and the palpi; body length 0.86 (0.86-0.98) mm. Carapace similar to that of other species of the genus, triangular in general outline and widest across the posterior margin; one pair of eyes; setae of carapace sparse and arcuate, each with a small spinule on the outer margin; about eight setae along the posterior carapacic margin; sculpturing of the dotted-reticulate type, with some granules extending posterior to the margin and giving the general impression of marginal teeth; carapace 0.27 (0.25-0.295) mm. long, 0.35 (0.35-0.39) mm. wide, width of carapace at level of eyes varying from 0.15 to 0.17 mm. Abdomen with tergal halves very sclerotic and well separated, strong dotted-reticulate granulations with many granules extending posterior to the edge of the sclerotic plate and appearing as rounded marginal teeth; setae arcuate, relatively fine, and apparently with a single spinule on the outer surface of each; each tergal half of the central portion of abdomen with eight to ten setae, chiefly arranged along the posterior margin. Sternites with half-sternites well separated, less sclerotic than the tergal halves, and with sculpturing that approaches a reticulate pattern; setae varying from acuminate to weakly arcuate, the arcuate setae apparently with a minute spinule; about eight setae along the margin of each sternal half. Abdomen 0.59 (0.59-0.69) mm.

long, 0.56 (0.54-0.60) mm. wide.

Chelicera small; light in color; flagellum of three setae, of which the most distally placed one is bladelike; serrula exterior of ten ligulate plates; subapical lobe of movable finger very small to obsolete; four or five very small denticles appear along the distal portion of the inner margin of the fixed finger; galea well developed, narrowing gently toward the distal end and terminally trifid; chelicera of holotype 0.089 mm. long, movable finger 0.058 mm. in length.

Palpus relatively stout, rich golden color; strongly granulate except the distal half of the chela and the chelal fingers; setae well developed, arcuate, and with a small spinule on the outer surface except that setae are acuminate on the distal half of the chelal hand and on the fingers; measurements given are overall and include the surface granulations. Trochanter with nearly square pedicel well separated from the rest of the podomere; flexor margin of trochanter with a basal-lateral and a medial-subdorsal bulge or protuberance; length of trochanter 0.14 (0.132-0.148) mm., width 0.085 (0.085-0.096) mm., length 1.65 (1.41 to 1.73) times the width. Femur stout, subcylindrical except for the well-developed and nearly square pedicel; flexor margin nearly straight or a very little convex; extensor margin weakly concave in the central half; greatest width just distal to the pedicel; length 0.245 (0.237-0.265) mm., width 0.070 (0.070-0.078) mm., length 3.5 (3.24 to 3.52) times the width. Tibia stout; pedicel nearly square; extensor margin usually evenly and markedly convex, flexor margin decidedly bulging in the center and a little concave beyond; length 0.202 (0.195-0.213) mm., width 0.089 (0.089-0.097) mm., length 2.27 (2.13 to 2.32) times the width. Chela from the dorsad stout, hand subtriangular, pedicel a little displaced towards the extensor surface, both extensor and flexor margins of hand weakly convex; chela without pedicel 0.331 (0.331-0.358) mm. long, 0.125 (0.121-0.136) mm. wide, length 2.65 (2.54 to 2.78) times the width. From the side, chelal hand fairly robust, oval in general outline; basal margin rounded and with the pedicel near the center of the margin; dorsal margin nearly straight, ventral margin weakly and evenly convex; fixed finger nearly straight and with a sinuation on the outer surface near the finger base; movable finger slightly curved ;each finger with usually 12 to 15 marginal teeth along the distal half of the inner finger margin, these teeth retroconical and acute at the distal end of the row but becoming obsolete and flattened near the center of the finger margin; both fingers with venom apparatus; tactile setae as shown in the figures; chelal hand 0.161 (0.159-0.173) mm. long, 0.109 (0.106-0.117) mm. deep; movable finger 0.175 (0.175-0.195) mm. long.

Legs golden yellow; sculpturing ranging from fairly strong granulations in the proximal podomeres to a virtual absence of granulations on the distal podomeres; setae ranging from arcuate with a minute spinule on the femur to acuminate on the flexor surface of the tarsus; no indication of a subdivision of the femora; measurements are for the holotype only. First leg with extensor margin of femur irregular

and weakly convex, flexor margin nearly straight; femur 0.159 mm. long, 0.048 mm. deep; tibia with extensor margin convex in the basal half but nearly straight beyond, flexor margin strongly convex and bulging beyond the pedicel, length 0.113 mm., depth 0.041 mm.; tarsus subtriangular and slender, length 0.128 mm., depth 0.030 mm. Fourth leg with podomeres similar in outline to those of the first leg except that the tibia is less stout and has a much less convex flexor margin; femur 0.218 mm. long, 0.058 mm. deep; tibia 0.156 mm. long, 0.043 mm. deep; tarsus 0.152 mm. long, 0.031 mm. deep.

Genital complex simple; 12 or less acuminate setae in a row along the posterior margin of the posterior operculum (third sternite) and a few setae on the surface of the operculum; cribriform plates somewhat oval (hemispherical in side view) in outline, median one appearing larger than the lateral ones.

Male: In all respects essentially like the female, although the chelicerae have been lost and consequently are not available for study. Only one male, the allotype, known. Body about 0.85 mm. long; carapace 0.27 mm. long, 0.34 mm. wide; abdomen 0.57 mm. long, 0.54 mm. wide. Palpus with trochanter 0.140 mm. long, 0.083 mm. wide; femur 0.237 mm. long, 0.066 mm. wide; tibia 0.195 mm. long, 0.086 mm. wide; chela about 0.335 mm. long, width 0.124 mm.; chelal hand 0.163 mm. long, 0.105 mm. deep; movable chelal finger about 0.17 mm. long. First leg with femur 0.152 mm. long, 0.047 mm. deep; tibia 0.109 mm. long, 0.039 mm. deep; tarsus 0.122 mm. long, 0.029 mm. deep. Fourth leg with femur 0.21 mm. long, 0.058 mm. deep; tibia 0.155 mm. long, 0.040 mm. deep; tarsus 0.152 mm. long, 0.032 mm. deep. Genital complex with 12 acuminate setae along the posterior edge of the posterior operculum; anterior operculum with 12 very fine setae along the medial portion of the posterior margin and a few longer setae on the face of the operculum.

Tritonymph: Description based on two paratypes; measurements so agree in the two that all measurements are given as the average of the measurements for the two individuals. General appearance like that of the adult except smaller in body size and lighter in color. Body 0.82 mm. long; carapace 0.24 mm. long, 0.30 mm. wide. Chelicera with nine plates in the serrula exterior; galea much as in the female. Palpus much like that of the adult except podomeres with less attenuated outline; no more than a very weak sinuation on fixed finger near base of outer margin; chelal fingers with tactile setae much as in the adult, with seven on the fixed and two on the movable finger; palpal trochanter 0.118 mm. long, 0.078 mm. wide; femur 0.199 mm. long, 0.066 mm. wide; tibia 0.174 mm. long, 0.079 mm. wide; chela 0.309 mm. long, 0.105 mm. wide; chelal hand 0.156 mm. long, about 0.094 mm. deep; movable chelal finger 0.163 mm. in length.

Deutonymph: Description based on one paratype. Body and appendages light in color, much less sclerotic than in the adult; body length 0.57 mm.; carapace 0.21 mm. long, 0.28 mm. wide. Chelicera with eight

plates in the serrula exterior; galea like that described for the adult. Palpal podomeres with granules weaker than in the adult; setae like those of the adult but fewer in number; femur subcylindrical in outline, pedicel wide; pedicel of tibia almost obsolete, flexor margin evenly convex; chelal hand much less triangular than in the adult; fixed finger with three interior and three exterior tactile setae, movable finger with one; palpal trochanter 0.101 mm. long, 0.058 mm. wide; femur 0.167 mm. long, 0.056 mm. wide; tibia 0.136 mm. long, 0.062 mm. wide; chela 0.264 mm. long, 0.085 mm. wide; chelal hand 0.140 mm. long, 0.078 mm. deep; movable finger 0.128 mm. long.

Protonymph: Description based on two protonymphs, with measurements given as the average for the two. Much like the deutonymph except smaller and palpal femur with weakly convex flexor and extensor margins. Body length 0.56 mm. Palpal trochanter 0.084 mm. long, 0.056 mm. wide; femur 0.128 mm. long, 0.048 mm. wide; tibia 0.117 mm. long, 0.057 mm. wide; chela 0.240 mm. long, 0.078 mm. wide; chelal hand 0.113 mm. long, 0.074 mm. deep; movable chelal finger 0.125 mm. long; fixed chelal finger with two exterior and one interior tactile setae; movable finger with one tactile seta.

Type locality: Pinkstaff, Lawrence Co., Ill. The type lot consists of the female holotype, the male allotype, ten female paratypes, two tritonymph paratypes, one deutonymph paratype, and two protonymph paratypes taken by H. Tiffany from a "tree hole" on July 25, 1950. The collection was submitted by Orlando Park of Northwestern University. This is the second instance of a species of *Cheiridium* recorded from North America, the previous record being of *C. insperatum* Hoff and Clawson, 1952, from Utah.

Remarks: *Cheiridium firmum* differs from most other species of the genus in absolute size of palpal podomeres and differs from all other species of the genus in the much smaller length: width ratios of the palpal podomeres. In absolute size, the new species most nearly approaches *C. minor* Chamberlin, 1938, from China, but *C. firmum* may be separated from *C. minor* by the stouter and differently shaped palpal podomeres.

GENUS *Apocheiridium* Chamberlin

Apocheiridium Chamberlin, 1924, Pan-Pac. Ent., vol. 1, p. 34.

Apocheiridium Beier, 1932, Das Tierreich, vol. 58, p. 10.

Members of this genus may be recognized by the following combination of characters: 11 abdominal tergites visible from above, posterior margin of carapace and tergites without posteriorly projecting toothlike spurs or serrations, the movable finger of the chela with a single tactile seta, granulations squamose-stellate in nature, and investing setae of the palps and body nonclavate. The genus is virtually cosmopolitan, with at least one species in every one of Wallace's regions except the Australian. In the United States, three species have been recorded from the Rocky Mountain and Pacific regions.

Genotype: *Apocheiridium ferumoides* Chamberlin, 1924.

Apocheiridium stannardi, new species

(Figs. 3 and 4)

Female: The description of the female is based on the female holotype and two female paratypes. Measurements given are for the holotype except that in some instances the measurement of the holotype is followed in parentheses by the range for all three females. In general appearance much like the genotype, *A. ferumoides*, as pictured by Chamberlin (1931, fig. 66). Body and legs light yellow in color, anterior portion of carapace darker; palpi light yellowish brown. Body robust; legs and palpi slender in comparison with body; body 1.21 (1.21-1.32) mm. long. Entire animal strongly granulate except the sternites; granulations of carapace stellate in appearance. Setae of tergites acuminate, virtually all others arcuate with a strong submedial spine on the outside margin of each. Carapace with usually 18 to 20 setae along the posterior margin; one pair of eyes; carapace 0.40 (0.40-0.41) mm. long, 0.415 (0.415-0.44) mm. in greatest width across the posterior margin; width of carapace measured at the level of the eyes 0.23 mm. for the holotype. Tergites strongly granulate; tergites 1 to 9 divided; each tergal half of center of abdomen with as many as 15 to 18 setae, most of which form a marginal row but as many as six may be grouped transversely across the lateral end of the tergal half. Sternites with almost smooth surface and with weak indications of division into halves in the central part of the abdomen; central tergal halves with as many as 12 or 13 marginal setae. Abdomen for all specimens between 0.65 and 0.70 mm. in width.

Chelicera light yellow in color; fixed finger with four or five marginal teeth; subapical lobe of movable finger well developed; flagellum of three setae; serrula exterior apparently composed of nine ligulate plates; movable finger with three nearly terminal and simple galeae (often broken and difficult to observe). Chelicera of holotype 0.089 mm. long, base 0.050 mm. wide, movable finger 0.066 mm. long.

Palp relatively slender, investing setae strongly arcuate, each with a submedial spine on the outside surface; surface of podomeres except the distal portion of the chelal hand and fingers very granulate, the granules nodular and extending well above the surface of the podomeres. Measurements of the palpal podomeres are overall measurements and include the granules. Trochanter with pedicel well separated from the rest of the podomere; flexor margin evenly convex, extensor margin with a central protuberance; length of trochanter 0.159 (0.159-0.175) mm., width 0.098 (0.098-0.106) mm., length about 1.65 times the width. Femur subcylindrical but widened and bulging on the extensor margin just distal to the well-separated pedicel; both extensor margin and flexor margin a little concave; pedicel about as wide as long; length of femur 0.311 (0.311-0.331) mm., width greatest just distal to the pedicel and equal to 0.077 (0.077-0.082) mm., length 4.05 (4.0 to 4.05) times the width. Tibia with central portion of the extensor margin weakly concave but weakly convex near each end; flexor margin in general moderately convex; length 0.260 (0.260-

0.272) mm., width 0.082 (0.082-0.089) mm., length 3.17 (2.95 to 3.17) times the width. Chela proximally stout, hand much narrowed towards the finger bases; flexor margin of hand basally rounded, extensor margin gently convex, basal margin somewhat rounded and merging gently with the flexor and extensor margins; fingers slender and gently curved; chela without pedicel 0.393 (0.393-0.420) mm. long, 0.122 (0.122-0.130) mm. wide, length 3.22 (3.1 to 3.35) times the width. From the side, chelal hand fairly stout, fingers slender and nearly straight; chelal hand with ventral margin gently convex, dorsal margin often a little more convex and somewhat swollen in the proximal half, basal margin rounded with pedicel displaced slightly towards the ventral side; hand without pedicel 0.178 (0.178-0.191) mm. long, 0.097 (0.097-0.105) mm. deep; movable finger 0.217 (0.217-0.233) mm. long. Both fixed and movable fingers with as many as 12 retroconical marginal teeth, these becoming progressively reduced until they are vestigial at a point well proximad to the midpoint of the finger; tactile setae placed as indicated in the figures.

The legs in general appearance and in shape of the podomeres are essentially like the legs of *A. ferumoides* as pictured by Chamberlin (1931, figs. 44-H,-I). Measurements of the KOH-treated first leg of the holotype include: femur 0.160 mm. long, 0.060 mm. deep; tibia 0.105 mm. long, 0.043 mm. deep; tarsus 0.101 mm. long, 0.031 mm. deep. The fourth leg was not treated with KOH and measurements for the holotype include: trochanter 0.085 mm. long, 0.058 mm. deep; femur 0.214 mm. long, 0.062 mm. deep; tibia 0.147 mm. long, 0.042 mm. deep; tarsus 0.130 mm. long, 0.031 mm. deep.

Genitalia with 12 to 14 marginal setae on the posterior margin of the posterior operculum or third sternite and a few other setae on the surface of the operculum; lateral cribriform plates very long and slender, median cribriform plate much smaller and nearly circular in outline.

Male: Description based on the male allotype. Male very similar to the female, except that at least in our single specimen the body and legs are a darker yellow; body length 1.12 mm.; carapace 0.37 mm. long, 0.41 mm. in greatest width across the posterior margin; abdomen 0.60 mm. in greatest width. Chelicerae lost from the specimen. Palpus as in the female; trochanter 0.171 mm. long, 0.105 mm. wide; femur 0.315 mm. long, 0.082 mm. wide; tibia 0.264 mm. long, 0.090 mm. wide; chela without pedicel 0.412 mm. long, 0.133 mm. wide; chelal hand without pedicel 0.185 mm. long; movable chelal finger 0.232 mm. in length. Legs essentially as in the female. Posterior operculum with 15 marginal setae and with about ten setae in a group just posterior to the genital opening; anterior operculum with two submedially placed setae.

Nymph: Accompanying the adults is a single nymph, probably a protonymph. Since a series of nymphs is not available, it appears advisable to omit description of the nymph at this time.

Type locality: Herod, Ill. The female holotype, the male allotype,

two female paratypes, and one nymphal paratype taken from beneath the bark of an oak tree by Burks and Stannard on April 4, 1948. This is the first record of a species of the genus *Apocheiridium* east of the Rocky Mountain Region in North America. Known only from the type collection.

Remarks: The present species is the tenth described for the genus. Of the five previously described Palearctic species, our new species appears to have considerable affinity with three: *A. ferum* (Simon, 1879) from southern Europe, *A. ferumoides* Chamberlin, 1924, from California, and *A. inexpectum* Chamberlin, 1932, from California. *Apocheiridium stannardi* differs from *A. ferum* (as described by Beier, 1932) by having a stouter chela and by having a movable chelal finger much longer than the length of the chelal hand without the pedicel. In addition, the flexor margin of the tibia in the new species is more conspicuously convex than in the species *A. ferum* as shown in drawings by Chamberlin (1931, fig. 29-N) and Beier (1932, fig. 7). From *A. ferumoides*, the new species may be separated by the difference in relative position of the external and internal basal setae of the fixed chelal finger, the difference being easily seen when our specimens are compared with the figure of *A. ferumoides* given by Chamberlin (1931, fig. 38-E). Also the palpal podomeres of *A. stannardi* are conspicuously smaller than those of *A. ferumoides*. From *A. inexpectum*, the new species is differentiated by a stouter chela and by having more conspicuous investing granules on the palpal podomeres. The tactile setae of the fixed chelal finger of *A. stannardi* approach in position those of *A. mormon* Chamberlin, 1924, as indicated by a comparison of our specimens with the figure given by Chamberlin (1924, fig. J) but *stannardi* and *mormon* may be separated without difficulty by the much more slender palpus of the latter.

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COLLEGIATE

CAVES OF THE KINKAID LIMESTONE NEAR COBDEN, ILLINOIS

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Numerous caves are known in the outcrop area of Mississippian limestone which extends across the southern counties of Illinois. Most of the caves are only of moderate size and are not spectacular from the commercial point of view. However, they are of considerable geologic interest. A few of the larger caves such as Cave Hill Cave and Cave-in-Rock Cave have been described in the geologic literature.[1] Our study concerns five caves in the Kinkaid limestone in a small area near Cobden, Union County, Illinois.

The Cobden area is shown on the accompanying map (fig. 1). It is within the Shawnee Hills section of the Low Interior Plateau physiographic province. The northern margin of the province marks the southern boundary of advance by the Illinoian glacier. This glacier almost reached the Cobden area and actually dammed the north-flowing streams and caused a temporary reversal of flow.

Topography

The topographic map of the area (fig. 2) shows a mature region of hills and valleys. The relief is on the order of 200 to 300 feet. Very little flat upland remains, and little flood plain exists along the valley bottoms.

The topographic divide is a prominent south-facing escarpment trending east-west across the area. The north-flowing streams rise close to the margin of the escarpment. They flow parallel to each other, and have a dendritic pattern of tributaries. Most of the south-flowing streams have steep headwaters rising on the escarpment face, but a few have breached the escarpment. These have captured the headwaters of north-flowing streams, and their deeply dissected valleys have cut off outliers, such as Buck Knob.

The escarpment face is divided into two bluffs by a terrace-like bench. The bluffs are formed by massive sandstones and the bench is caused by the intervening weak Kinkaid limestone. Actually much of the bench is underlain by the Degonia sandstone stripped of the limestone cover.

Line AB on figure 2 shows the location of a cross-section profile (fig. 3) drawn from Drury Creek valley southward across the escarpment. Here we see Wing Hill as the dominant upper bluff, the bench, and the lower bluff. The gentle northward dip of the rocks controls backslope topography. Guthrie Cave is low and accordant to the Drury

[1] Bretz, J Harlan, Vadose and phreatic features of limestone caves: Jour. Geol., vol. 50, pp. 752, 757, 758, 1942.

Creek Valley; Rich's Cave is somewhat higher but also on the backslope; and Cobden Cave is high on the escarpment face.

FIG. 1.—Location of Cobden area, Union County, Illinois.

STRUCTURE

The regional dip of the rocks is toward the north at an angle of 1 to 2 degrees with some modifications of direction and angle by local structures. Structure maps of the area have been drawn by St. Clair[2] and Lamar[3].

STRATIGRAPHY

The geologic map of the Carbondale quadrangle by Lamar[4] covers most of the area under consideration, except for a portion of the Alto Pass quadrangle. That area has been mapped by J. M. Weller and G. E. Ekblaw.[5] The outcropping rocks are the uppermost units of the Mississippian Chester series and the Pennsylvanian Pottsville series. The units significant to our study are the Degonia sandstone and the Kinkaid limestone in which the caves occur, both of Chester age, and the Pennsylvanian Lick Creek sandstone and conglomerate.

The Degonia sandstone is a massive cliff-forming formation from 75 to 125 feet thick in the region of study. It forms the lower of the two cliffs which cap the escarpment. The sandstone is composed of clean white fine to medium-grained, angular sand. Absence of pebbles distinguishes it from the younger Lick Creek sandstone. Typically the natural exposure is weathered grayish buff, and the ledges are covered with lichens. Thin shales are intercalated in the upper portion, and the lower portion is transitional into the underlying shales and limestones of the Clore formation. The middle portion of the Degonia is the prominant massive member.

The Degonia has a broad outcrop distribution. It not only forms the prominent scarp but much of the bench and the southern part of the backslope of the escarpment. A broad area north of Cobden is immediately underlain by the sandstone with only a thin cover of loess.

The Kinkaid limestone is significant as the soluble host to the caves of the study. The formation is reported to be 140 feet thick at the eastern extremity of the area near Lick Creek and Lilly Cave, but thins progressively, though apparently irregularly, toward the west. The variation in thickness is due to pre-Pennsylvanian erosion, which com-

[2] St. Clair, Stuart, Oil investigations in parts of Williamson, Union and Jackson counties: Illinois Geol. Survey Bull. 35, p. 50, 1917.

[3] Lamar, J. E., Geology and mineral resources of the Carbondale quadrangle: Illinois Geol. Survey Bull. 48, pp. 133-140, 1925.

[4] *Op. cit.*

[5] Weller, J. M., and Ekblaw, G. E., Preliminary geologic map of parts of the Alto Pass, Jonesboro, and Thebes quadrangles: Illinois Geol. Survey Rept. Inv. 70, 1940.

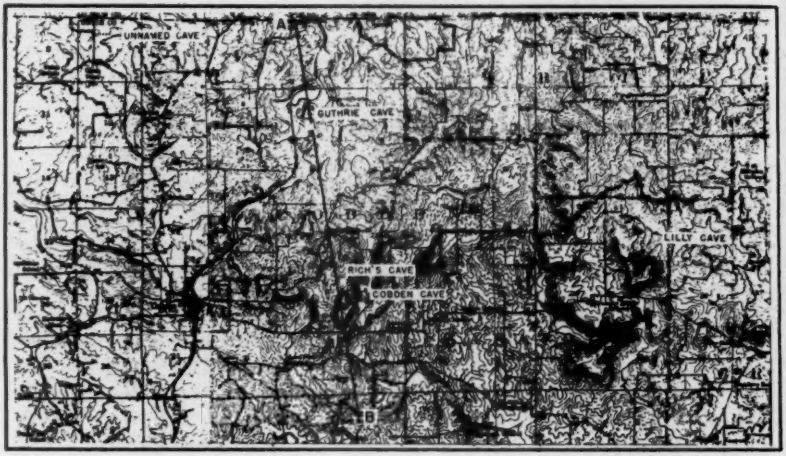

FIG. 2.—Topographic map of the Cobden area showing cave locations.

pletely removed the limestone from the Alto Pass area. The Kinkaid limestone rests conformably on the Degonia formation.

The Kinkaid formation is composed dominantly of limestone ranging in texture from lithographic to coarse-grained calcarenite, and in color from light brown to buff, bluish gray, dark gray or nearly black. It weathers to pale gray or yellowish brown. Irregular, flattened chert masses occur at certain horizons. Well-bedded chert layers occur in a few places, such as in the roof near the entrance of Cobden Cave. The chert is dark brown to black, commonly mottled by lighter-colored crinoid and other fossil fragments. A siliceous limestone is exposed in Cobden Cave. Here the carbonate has been dissolved, leaving spongy projections which are easily broken by a hammer blow. Most of the purer limestone is very dense and difficult to break. Fossils are common.

Shale and shaly limestone are common in the formation but are seldom well exposed. A few shaly beds occur near the entrance to the caves and several very shaly layers are exposed near the roof of Guthrie Cave. Eight feet of thin-bedded gray and pinkish clay shales were noted about 50 feet below the base of the Pennsylvanian conglomerates in an undercut slope on Drury Creek in the middle of section 16 T. 11 S., R. 1 W.

The Kinkaid limestone has a broad distribution only where it is thick near Lilly Cave and on the bench along the headwaters of the creek which flows into Little Grassy Lake. It occurs in the lower slopes beneath the resistant cliff-forming Pennsylvanian sandstones which form the highest ridges and knobs of the backslope of the escarpment. The limestone occurs in steep slopes along Drury Creek and apparently caps some of the low hills west of the creek. In the Alto Pass quadrangle the limestone apparently is broadly

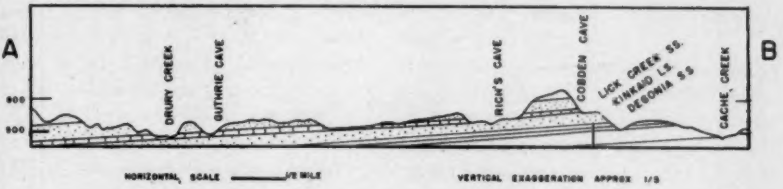

FIG. 3.—Section across the Cobden escarpment.

distributed on the backslope of the escarpment and northward along Mill Creek almost to Jackson County line. It is marked throughout its distribution by development of sink holes.

Three Pennsylvanian formations occur in the area. Of these, only the lowermost Lick Creek sandstone and conglomerate are significant to this study. The overlying Drury shales and Makanda sandstone are present near the escarpment only on the higher ridges such as Wing Hill in sec. 27, T. 11 S., R. 1 W. The Makanda sandstone is the dominant rock a few miles to the north.

The Lick Creek sandstone is typically a medium- to coarse-grained, massive, white sandstone which weathers to a buff color. Throughout the area of this study irregular conglomerate beds of white quartz pebbles are present.

This formation forms the higher portion of the escarpment proper or may form a second rise some distance away from the lower Degonia bluff. Cobbles derived from it are found abundantly in all the creeks, and in the caves.

Loess of Pleistocene age rather generally mantles the region. It has been eroded from the steepest slopes but has accumulated to a depth of several feet on the lowlands. It caps the uplands and is the parent material of modern soils. It has significance in this study because it is the source of the silt which forms part of the fill in the caves.

Terrace deposits occur in the valleys but are not important to the present study.

THE CAVES

The topographic positions of the five caves are shown on figure 2.

(a) Guthrie Cave is at the northern limit of the limestone outcrop on Drury Creek, and the mouth is accordant to the valley floor.

(b) An unnamed cave (now called Union Point Cave) is near the northern extremity of the limestone outcrop on Mill Creek, but like

(c) Rich's Cave occurs low in the valley. The streams which emerge from them cascade several feet to the valley bottom.

(d) Cobden and Lilly Caves occur high on the south-facing escarpment and do not seem to be related to the adjacent valleys.

Rich's cave has a large mouth with a flat roof and a prominent cascade from mouth to stream. There are also two known entrances through sink holes. The only known openings to Cobden and Lilly Caves are through

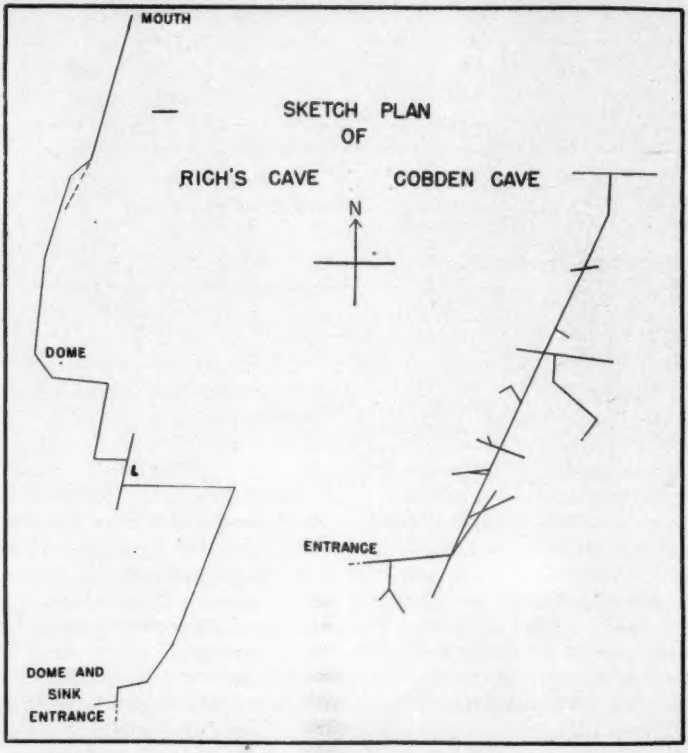

FIG. 4.

sink holes; the entrance to the latter is actually through a joint in the base of the Lick Creek sandstone.

All of the caves investigated are developed in the Kinkaid limestone. Other caves in the lower Chester and Meramec limestones are known and have been entered by the authors but are not here discussed. Cave Hill Cave in Gallatin County, best known of southern Illinois Caves is also in the Kinkaid limestone.

It is interesting that most of these caves have formed close beneath the Pennsylvanian Sandstone contact. The only exception appears to be Rich's Cave. The stratigraphic position within the Kinkaid itself is not constant, however, because the post-Mississippian erosional unconformity beveled the formation. Whereas Lilly Cave must occur in uppermost Kinkaid, Guthrie, and Union Point caves must be in the lower portion of the formation.

Solution work has been controlled by the jointing of the limestone. In the two caves which have been mapped (fig. 4) three principal joint sets and several minor joint sets are developed. The joints trending N. 25° E., N. 85°E., and N. 15°W. are domi-

nant in Rich's and Cobden caves. These caves are representative of the two basic patterns of cave development. Rich's Cave is a longitudinal cave with a single passage which turns sharply from one joint system to another. A few detritus-filled side passages do occur in this cave. The general trend is down the dip of the rocks. Guthrie Cave has two tributary streams joining the main passage. Cobden Cave (also shown in fig. 4) has a network pattern, although the open passage is now longitudinal. The original solution cavern appears to have been an intricate network of connected passages developed along three main joint sets. Lilly Cave is a particularly striking example of a network cave developed along two sets of joints crossing nearly at right angles.

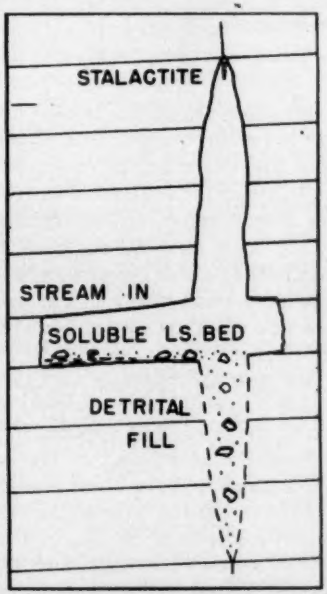

FIG. 5.—Diagrammatic representation of solution work in a part of Rich's Cave, Union County, Illinois.

Solution has been localized along the nearly vertical joint planes. Commonly solution work has been dominant in a certain bed and hence widening has occurred there. The inner portion of Rich's Cave is a narrow slot tapering upward to a peak, or a dripstone fill (fig. 5). The floor here is covered by rubble, and hence the lower portion of the profile is uncertain. However, deep holes where the stream crosses the slot suggests a floor profile similar to that of the roof. In Rich's, as in the other caves, the broadest portion of the caves is almost invariably a dense, light gray, sublithographic limestone. Adjacent coarser crystalline limestones and even siliceous horizons (notably in Cobden Cave) have also been dissolved. In some caves the roof is a flat resistant bed of relatively insoluble rock. The flat roof at Cobden Cave (fig. 6) is a bed of chert in the entrance passage, and a very siliceous horizon beyond that. Here the joint is generally visible in the roof but commonly opens out only in small ceiling cavities. Ceiling and wall cavities developed along joints in all caves. They extend outward from the main passage only a short distance and then come to a dead end. There is no evidence that water entered the cavity except from the cavern itself.

Domes rise above the main passage in Rich's, Guthrie, and Union Point caves. In each case the dome leads to a sink hole. The joints have been enlarged by percolating water. Vertical solution has grooved the walls. Dripstone and flowstone occur along

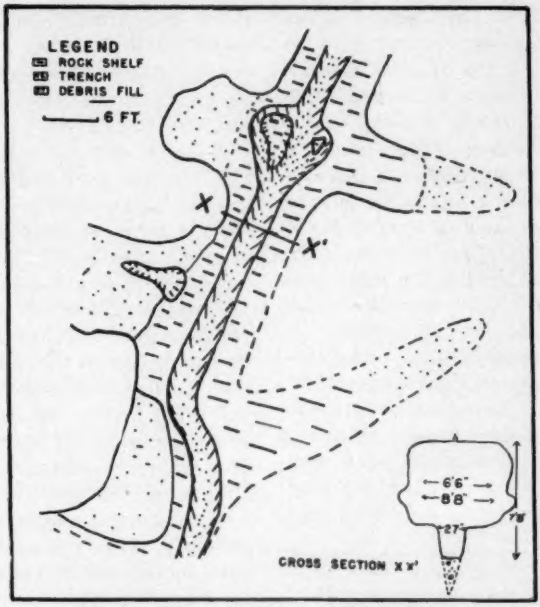

FIG. 6.—Plan of portion of Cobden Cave.

with solution features in the same dome.

A second level is well developed in a part of Guthrie Cave. It follows the same joint as the lower stream-filled passage, and an open slot connects the two. Dripstone fills the roof cavity of the upper level. Rich's Cave also has an upper passage, but it has not been investigated thoroughly by the authors. Gray clay from the shaly limestone makes progress difficult. It, too, has a central floor slot connecting to the lower passage.

Tubular openings occur in Rich's, Guthrie, and Cobden caves. Each has developed along a joint and now has a flow of water through it. Each tube is apparently being actively enlarged and appears much younger in development than the main cave. The tubes in Guthrie and Cobden caves are too small to enter. The one in Cobden Cave carries a tributary flow of water, apparently from a sink hole; in Guthrie Cave the main flow of water leaves the traversable cave passage through a small tube and then rejoins it some distance beyond.

The tubular passage in Rich's Cave is markedly different from the rest of the cave, and appears to be of relatively recent origin. The passage occurs in a dense blue limestone. It is about 125 feet long and has an oval cross section about 2½ to 3 feet high; it is somewhat wider than high. The controlling joint is obscurely visible, though no ceiling slot has developed along it. Some cross joints are slightly enlarged, and, in

wet weather, one carries a small stream of water.

The tube shows every evidence of active enlargement. The floor, walls, and ceiling are smooth and dense and extensively fluted. The floor is generally covered by several inches of sand, but on several occasions the writers have crawled across the nearly bare, fluted floor. Twigs and grass on the roof are evidence that the passage is sometimes entirely filled by water.

The passages at each end of the tube are broader and higher, have a flat roof, and apparently do not fill completely with water. The tube follows a joint intersecting these passages at a sharp angle. Furthermore, close to the intersection at each end of the tube, there is a rubble-filled opening which probably marks the former passageway.

Anastomosis is described by Bretz as a "multitude of small, sinuous passages along a bedding plane, the earliest attempt at caving-making in a formation."[6] Such small interconnected passageways are well developed along the wall and in some of the ceiling blocks in Rich's Cave. They are clearly the work of solution. Bretz suggests that they form under phreatic conditions but it occurs to the authors that they might also form beneath the surface of a water-table stream or at times when the cave is full of water. Ample evidence that these caves are sometimes filled with water includes the presence of small sticks, leaves, and sand on near-ceiling ledges, fluting high on the walls and (in the case of Rich's tubular passage) on the ceiling itself.

[6] Bretz, J Harlan, Vadose and phreatic features of limestone caves: Jour. Geol. vol. 50, p. 706, 1942.

Complete rock spans have not been observed in the passages of these caves although they are well developed in the Sensemeyer Cave in Meramec limestone below the escarpment. However, a well-developed partial rock span occurs in Cobden Cave. A narrow partition of undissolved limestone hangs from the ceiling for a distance of about 10 feet. It is only 6 inches to a foot thick but hangs down about 3 feet from the roof. It is rough and weathered like the walls and shows no evidence of recent contact with a body of water. It is difficult to visualize the formation of such a partition except by solution work at a time when water surrounded the partition itself.

Vertical grooving caused by the solvent action of water flowing over the surface of the limestone has already been mentioned in connection with the domes. Similar parallel groovings occur along ledges which normally stand above the modern subterranean stream. They are recent features and may be formed by the sheet-like flow of water which moves down the walls in some parts of these caves.

Flutings are a series of cupped depressions very much like ripple marks. However, they are solution features in the limestone. The steep face is on the up-current side of the cup and the gentle slope on the down-current side. These apparently retreat upstream as the result of more rapid solution because of turbulance below the steep face. The flutings are well developed and active today in the fine-grained blue limestone in Rich's and Guthrie caves. They occur only where the stream covers the surface.

Deposition

Secondary carbonate deposits are abundant only in Lilly Cave. Rich's Cave has a few small stalactites actively growing today in the passages adjacent to room L (fig. 4). In room L there is a large column about 2 feet in diameter and many stalactites which have formed along the major roof joint. Near the mouth of Guthrie Cave the roof is covered by a multitude of slender stalactites one to three inches long and apparently growing. Only some 100 feet or so inside the cave conditions for precipitation are not favorable and dripstone and flowstone are found only at the domes or along roof joints where considerable water enters.

Lilly Cave is essentially dry today and no water enters the joints. However, great masses of stalactites, stalagmites, columns, and flowstone occur in the passages. Some passages are blocked by this secondary material. In the passages near the ground surface there are crusts of flowstone interbedded with silt deposits. Some crusts are several inches thick. Similar flowstone has developed in the Cave Hill Cave in Saline County.

Crystals of calcite form a veneer over the roof and walls of part of Lilly Cave. The calcite crystals are mostly small (less than ⅛ inch in length) but form a complete sheath ⅛ to ¼ inch thick. The crystals are clear to buff, containing some silt. We have not investigated to see if the crystals extend downward between wall and detrital fill.

All the caves contain detritus. Where there is flow of water the stream transports considerable sediment, but the trend seems dominantly to be the removal of material which had formerly been deposited in the caves.

The modern streams transport silt, sand, and cobbles, apparently derived from the overlying Pennsylvanian sandstone and the mantle of loess. Deposits occur in protected places in the caves and, in low water, as bars and bottom deposits. The large load transported is apparent after heavy rains when changes in amount and location of material may be noted. The floor of most of the caves contains large blocks of limestone and cobbles of chert, limestone, sandstone, and conglomerate. The large blocks have obviously fallen from the roof and have not been transported far. The conglomerate and sandstone cobbles have been brought in from the overlying formations presumably through sink holes. So far as we have observed, the portion of the ridge above Rich's Cave does not now have a Pennsylvanian cover yet cobbles of this formation are abundant. These seem to have been derived, at least in part, from the older fill still present in side passage.

Evidences that the cobbles are transported today during high water are of two types: (1) imbricate arrangement on rock ledges and on the stream floor, and (2) piles of cobbles partially filling constricted portions of the cave. Illustrative of this is a place in Rich's Cave not far downstream from the sink entrance where there is a narrow vertical slot with a wide but low bedding cavity. The stream normally twists about in the bedding cavity, but at high water the bedding cavity is filled. A con-

striction in the vertical joint causes increased velocity, but just below the constriction a pile of cobbles has accumulated in the joint.

Ancient detrital fill is an outstanding characteristic of the caves. Lilly Cave has been so nearly filled that in most places the explorer must travel on hands and knees or by crawling flat on his stomach. The floor is largely silt but in one area visited by the writers it is red clay. Collapse of this debris in a few passages indicates some removal from a lower level. A spring occurs in the limestone about 75 feet below the cave entrance.

Lilly Cave is certainly the largest solution cavity which we have observed. It is not well known as we have not explored it extensively nor has it been mapped. Exploration is slow because of the restricted passages and poor circulation of air, but our preliminary investigation adequately indicates the nature of the cave and something of its size. Detritus seems not quite to have filled the cave—or possibly compaction has caused an opening of 6 inches to a foot in the large rooms. A somewhat higher passage exists along the joints. The former room cavities must have been large with a great flat roof. In the largest collapse area undissolved limestone pillars rise above the debris, but between pillars one can look out many yards in three directions over the top of the debris. Stratification of the silt and sand can be seen in one rather fresh collapse area.

A stream is actively removing fill from the Cobden Cave. The stream enters through a sink hole, flows along the joint, and at the far end has opened a small tunnel through more debris (fig. 4). A tributary, also opened by a stream, joins the main stream just before the tunnel. The tunnel is not large enough to penetrate and the tributary has not yet been investigated. The many cross joints shown in the diagram of Cobden Cave are filled by debris. Some of the cross joints appear originally to have been enlarged as much as the present passages, but have not been opened again. In some of them there is complete fill, in others a low passage between roof and fill is used by racoons. An occasional trickle of water is indicated by a small erosional channel at the lip of the fill. The stream flowing 6 to 8 feet below the roof has undercut the debris in the cross joint, eroding it some 20 feet or more. Rich's Cave also exhibits a few large cross-joint passages which have been filled by debris. Some are now filled to the roof, others have a passage large enough for racoons. Such filled passages have not been observed in either Guthrie Cave or Union Point Cave, although these caves have yet to be completely explored by the writers.

The sequence of fill visible in cross joints of Rich's and Cobden caves is the normal sedimentational sequence of coarse material at the botton and fine at the top. The lower several feet, where observable, invariably contain large blocks of chert, conglomerate, sandstone, and an occasional limestone cobble. These are surrounded by quartz sand and pebbles derived from the overlying sandstone. Excavation in one cross joint of Cobden Cave uncovered a block of unconsolidated, stratified

reddish clay, interbedded with silt. Whether or not this indicates the former existence of a red clay fill cannot be stated with certainty. The stratification is atypical.

The uppermost foot or two of fill contains no coarse material; it is well but finely stratified. In Rich's Cave a good section 8 inches thick is finely stratified buff silt. We believe this silt is derived from the loess mantle.

Extremely fine-grained unstratified red clay has been observed only in Lilly Cave in the Cobden area, although the large Cave Hill Cave and Ava Cave likewise contain it. The red clay in Lilly Cave was found in a passage from which the silt normally found above it had apparently been removed. This passageway was very close to the present surface of the ground as indicated by numerous flowstone deposits in the joints and across the top of the fill. The clay appears to be the typical colloidal clay described by Bretz and other cave workers. It is distinctly older than the coarser debris.

All the caves, with the exception of Lilly Cave, have a stream flowing through them. Erosion by solution and abrasion, by the sand load, is active. The limestone is smooth and polished in the stream bed and along the lower part of the walls, whereas the upper portion of the walls is pitted and irregular. Solution work in the upper part of the passages is much slower and apparently is brought about by a thin film of water.

Tributary branches are known in Guthrie and Cobden caves. Union Point Cave is T-shaped with the mouth at the base and tributaries along the arms. The water is always rather deep in this cave, as the entrance is at a higher elevation than the bottom of the arms. This cave has not been thoroughly studied yet. At high water it is not enterable. Solution work has been active to a level below the outlet, but the clastic load of silt and sand is moved out by the current.

The tubular passage in Rich's Cave is being actively enlarged by the stream. It appears to be a relatively recent feature and undoubtedly has been made largely by flowing water. The roof, as well as the walls, is fluted.

The role of the modern stream in Cobden and Rich's caves seems to be dominantly the removal of older debris fill. The network pattern of Cobden Cave and the several large cross-joint passages in Rich's Cave is strong evidence for a phreatic origin. Guthrie Cave shows far less indication of phreatic features although it alone is today near the valley bottom. The other caves, though now high above the valleys, contain such phreatic features as network pattern, anastomosis, tapering joint slots, joint-determined roof and wall cavities, and one has a partial rock span. The colloidal clay fill in Lilly Cave and the coarser debris in that and other caves indicate a history not attributable to the modern stream.

Review of Cave History

Although each cave shows special features, a general sequence of events may be suggested.

It is obvious that Lilly and Cobden caves, now high on the escarpment face, are not recently formed

caves. These appear to be the oldest caves and have the most complex history. Their network pattern of solution along joints indicates phreatic origin at a time when the water table stood high. Probably the escarpment was remote and the adjacent valleys shallow. Rich's Cave is on the back slope less than a half mile from Cobden Cave but nearly 100 feet lower. It, too, contains a few enlarged cross joints, but they are not so extensive as in the two caves just described. Apparently the cave is younger and may not have formed until the adjacent valley allowed rather rapid movement of groundwater toward it. Besides the partial network development, slotted vertical joints and anastomosis suggest phreatic origin.

After the major stage of solution, and possibly partly contemporaneous with solution, there came a stage of fill by fine-grained clays. This clay is believed to be residual from the limestone. Bretz suggests that it accumulated at a time of very slow groundwater circulation, possibly under conditions of peneplanation. The caves on the back slope of the escarpment probably never reached this stage.

Rejuvenation of the region near Lilly and Cobden caves brought about increased circulation of groundwater in the caves and partial removal of the clay. Much debris was carried into the cave, including cobbles up to a foot in length. Rapidly flowing water, presumably underground streams, must have transported this material. Sections of the debris in Lilly Cave do not extend to the bottom of the solution cavity, and such coarse material has not been seen in that cave. However, both Cobden and Rich's caves exhibit it in every debris-filled, cross-joint passage. The upper foot or 6 inches of material is finely stratified buff silt, derived largely from the loess mantle, and represents the final stage of fill.

The filling in these caves is not yet accounted for. The last deposit of silt suggests that the time was late Pleistocene. The Illinoian glacier terminated only a short distance north of the caves. Meltwater was ponded by the ice and overflowed southward across the escarpment along Drury Creek valley and probably along other valleys as well. Future study of the physiography of the area will investigate terraces on these streams, in the hope of determining whether or not the terracing may have raised base level sufficiently to cause sedimentation in the caves. This seems a reasonable possibility in respect to Rich's Cave, but is somewhat doubtful in respect to the very much higher Cobden Cave.

The last stage, still in progress, is the removal of detritus by subterranean stream erosion. Some additional solution is going on today, especially in the domes and along the floor of the caves, but the main cavities seem to have been formed in a previous cycle.

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THE ERICACEAE OF ILLINOIS

MARTHA H. BELL
University of Illinois, Urbana

The family Ericaceae, or heath plants, as represented in Illinois, are chiefly woody plants ranging from creeping shrubs to large shrubs and even small trees, e.g., *Vaccinium arboreum*. Some of the species look like herbs, but are actually small woody evergreens, e.g., *Pyrola*. Some of the herbaceous species lack chlorophyll and live saprophytically in rich woodland areas. The family contains several plants of economic importance, including blueberries, cranberries, and others, such as rhododendron, familiar to us because of their ornamental value.

According to Swingle, there are eighty genera and 1350 species in the family Ericaceae.[1] Twelve genera are represented in Illinois, and only twenty species occur here, most of them rarely.[2] Owing to their large numbers and social habit, the Ericaceae are very characteristic of the vegetation in many portions of the earth. They are found everywhere except in deserts and tropical regions. Ericaceae in North America is chiefly found in the acid bogs of the northern region and on high exposed hilltops, as in southeastern United States. In some areas, members of Ericaceae form vast stands to the exclusion of other plants.

The heaths, except for the monotropas, are plants of rocky and sandy soils. The prairie soil which covers most of Illinois is too heavy for them. Most of the ericaceous plants in Illinois are either in bogs in the extreme north or on well-drained slopes of the extreme south. Suitable northern areas are becoming smaller as the bogs are drained or gradually filled in by growth of sphagnum and by the washing in of mineral matter.

Nearly all Ericaceae, regardless of their environment, are more or less markedly xerophytic. The usefulness of this adaptation is easily seen when considering the species on dry hillsides or in sandy areas, but many of the Ericaceae grow in bogs, and even in shallow water. However, the ability of peat-bog plants to obtain water is limited by poorly developed root systems, the low oxygen content and poor aeration of the water, and root excretions and bog toxins. The various xerophytic adaptations of the plants enable them to live in this "physiologically dry" environment. The strongly cuticularized epidermis, the absence of stomata on the upper leaf surfaces, the well-developed palisade layer, the frequently sunken stomata, and coatings of waxy "bloom," hairs or scales, all tend to reduce the amount of water the plants lose by transpiration. In some ericaceous plants, notably Andromeda, the leaves are revolute, and the curled leaf margins reduce water loss by cutting down the circulation around

[1] Swingle, D. B., A textbook of systematic botany: New York, 1946.
[2] Jones, G. N., Flora of Illinois: Notre Dame, 1950.

the stomata. One xerophytic adaptation, the loss of leaves in winter, is not characteristic of bog ericads. It is vital to the existence of the plants that transpiration be at a minimum when the soil around their shallow roots is frozen. In winter, the leaves are upright with their dark upper surfaces curled inward, thus reducing the amount of radiant heat absorbed. The heat would raise the temperature of the mesophyll cells and lead to greater loss of water. Also of special value in winter is the ability of ericad leaves to absorb water vapor directly from the atmosphere.

This study of the Ericaceae of Illinois is based largely upon herbarium materials, supplemented by reference to literature on the subject. In any work concerned with plants it is essential to study the records in our herbaria—actual plant samples and information about their collection. The earliest plant collections in Illinois, by Michaux, were made 160 years ago. Though most of the collections are modern, the records of hundreds of collectors kept during this long period form the basis of our present work.

The Ericaceae have been treated by some authors as several families, largely because of differences in growth form. The saprophytic monotropas are placed in the Monotropaceae, the herbaceous pyrolas and chimaphilas in Pyrolaceae, and the woody plants, such as the vacciniums and Chamaedaphne, in the Ericaceae. Other workers have divided the Ericaceae, in its more limited sense, into two groups; one, with superior ovaries, includes Rhododendron and most other genera, and the other includes the vacciniums, which have inferior ovaries. The first division is based on vegetative characters derived from greater or lesser adaptation to parasitic or saprophytic habit; but the remarkable similarity of flower structure throughout the group leads to its treatment as a single family.

MEMORIALS

JOHN B. RUYLE
1897-1952

Dr. John B. Ruyle, President Emeritus of the Illinois State Archaeological Society and a member since 1932 of the Illinois State Academy of Science, died May 6, 1952, at his home in Champaign, Illinois, following an illness of several weeks.

Dr. Ruyle established what is believed to be a record in attendance at the annual meetings and field trips of the Academy, attending all Academy meetings and section meetings in anthropology from 1933 to 1951. He was seriously ill during the 1952 meeting at Eastern Illinois State College, Charleston, and deeply regretted his inability to attend.

Dr. Ruyle served as Program Chairman of the Section of Anthropology in 1936, 1937, 1938, and 1939. He was one of the organizers of the Illinois State Archaeological Society and in 1933 became its first President, continuing in that office until 1947.

Dr. Ruyle also served many years as President of the Champaign County Archaeological Society and was interested in the Society for American Archaeology, attending some of its meetings.

Dr. Ruyle was deeply interested in the scientific approach to the study of American Indian Archaeology. He strongly opposed destruction of indian mounds, village sites and camp sites. He cooperated fully with the Illinois State Museum and the Departments of Anthropology of the University of Chicago and the University of Illinois. He was especially interested in summer "digs" conducted by the Museum and the Departments of Anthropology of the two universities and frequently visited groups of students at work in the field.

He did not care to amass or own a collection of Indian artifacts, but he visited scores of large collections throughout the central West. He was more interested in acquiring a large and impressive scientific and historical library which ranked high among those of students of archaeology in the central West.

Dr. Ruyle held the bound volumes of the Transactions of the Illinois State Academy of Science and all journals and year books of the Illinois State Historical Society. He also owned many rare books bearing upon the American Indian in the central west and throughout the nation. Many of the periodicals and volumes which he acquired are now out of print. Some issues he found only after painstaking diligence and considerable expense.

Dr. Ruyle was much interested in the geology, archaeology, and history of southern Illinois and had participated in at least 15 of the "Ozark

Tours'' conducted by his long-time friend, the late L. O. Trigg, a newspaper publisher from Eldorado, Illinois. Dr. Ruyle knew intimately all sections of Illinois and made countless automobile tours of the nation, especially in the central and far West. He was much interested in zoology, being especially well informed upon birds and snakes. He had accompanied several of the biological field trips of the Department of Zoology, University of Illinois, to the Reelfoot Lake area of western Tennessee.

Although a practicing dentist, Dr. Ruyle found his great interest in life in scientific and historical studies. He took numerous courses in the University of Illinois, while maintaining his large professional practice. He spent his vacations and most of his week ends in field study in some branch of science.

His passing at the early age of 55 was keenly felt by his many friends in various fields of science. He always insisted he was an amateur, always a student, but frequently his knowledge approached professional status.

—C. C. Burford

WILLIAM OSCAR BLANCHARD
1886-1952

William Oscar Blanchard was born at Hilbert, Wisconsin, on January 13, 1886, the son of Merritt and Mary Gaiter Blanchard. All three of his degrees were awarded by the University of Wisconsin, the Ph.B. in 1910, in Physics, the Ph.M. in 1917 and the Ph.D. in 1921, both in Geography. However, his first two years of college, 1904-1906, were spent at Oshkosh Teachers College. He spent eight years as teacher, assistant principal and principal in high schools in Wisconsin, two prior to recipt of his bachelors and six between his bachelors and masters degrees. While working toward the doctorate, Blanchard held successively a fellowship, an assistantship, and an instructorship.

In the fall of 1921 Blanchard was brought to the University of Illinois as an assistant professor to teach geography courses in the Department of Geology. He rose in rank rather rapidly, becoming associate professor in 1925, and professor in 1930. It was principally in the fields of economic geography and the geography of Europe that he directed his interests in both teaching and writing. However, some of his attention was given to the preparation of ''interest stimulating devices'' for primary and secondary school pupil and teacher. Of the ninety entries which are included in his bibliography, one is a college textbook of which he was senior author, three are college workbooks, two are chapters of books at the college level, and two are Illinois editions of grade school geographies. Most of the others are articles which have appeared in various geographical journals published in this country.

Blanchard spent the summer of 1925 in travel and study in southern and western Europe, and the school year 1931-1932 on a trip around the world while on the only sabbatical leave he took during the almost

thirty-one years he was a member of the University of Illinois faculty.He taught summer sessions at Illinois 1922 through 1951, except for 1925 and the three summers when he taught at the University of Iowa, Pennsylvania State College and the University of Minnesota.

For twenty-seven years, Blanchard was adviser to both undergraduate and graduate majors in geography. In this time he came to know many students who did much of their work under his guidance. To them he will be remembered as a man who was willing at all times to give encouragement, and to offer suggestions when he felt the student would be benefited thereby. To his colleagues, his mere presence and his kindness will be missed.

He held membership in the Association of American Geographers, the National Council of Geography Teachers, the Illinois Academy of Science, Sigma Xi, Gamma Alpha, and the Urbana Exchange Club. In the Illinois Academy of Science he was especially active,having presented papers at nineteen of the twenty-nine meetings that have been held since he came to Illinois. He also strongly urged graduate students and younger members of teaching staffs to prepare and present papers on the Academy programs.

Blanchard was active almost to the very time of his death, which came most unexpectedly on March 7. During the morning he met his regularly scheduled class and had planned to work in his garden in the afternoon. He is survived by his wife, who was, before their marriage on June 14, 1933, Claribel Patterson, and an older sister who lives in Oshkosh, Wisconsin.

ACADEMY BUSINESS

SECRETARY'S REPORT OF THE BUSINESS OF THE ILLINOIS STATE ACADEMY OF SCIENCE FOR THE YEAR MAY 5, 1951 TO MAY 4, 1952

Compiled by PAUL R. SHAFFER, *Secretary*

The 45th annual meeting of the Illinois State Academy of Science was held on the campus of Eastern Illinois State College, Charleston, Ill., on May 2 and 3, 1952. The sectional program included 105 papers, and 475 individuals attended the section meetings.

The Junior Academy exhibits were of very high calibre this year and represented only those which had received first-place awards at the regional exhibits in the state. The program of the Junior Academy has been a vigorous one. Sectional meetings for the Junior Academy were instituted and a special time was set aside for the Senior Academy to visit Junior Academy exhibits and to discuss them with the exhibitors.

The general morning program on Friday, May 2, included the Presidential Address by Dr. Neckers, entitled "Scientists—More or Less?" Austin M. Brues, Director of Division of Biological and Medical Research, Argonne National Laboratory, spoke on "Neutron Activation."

The annual banquet was held Friday evening in the Cafeteria. The group adjourned to the auditorium of the Main Building, where the Illinois winners in the 11th Annual Science Talent Search program were presented with certificates. This year 26 high school boys and girls from the state received recognition. Four of the winners were awarded a Washington trip and the opportunity to compete for a national award. The top winner in the nation was one of the four Washington trip winners from Illinois.

The annual public lecture, presented by L. F. Audrieth, Professor of Chemistry, University of Illinois, was entitled "Born Thirty Years Too Soon."

COUNCIL MEETINGS

The Council held four meetings during the year. The first meeting of the Council followed the Council breakfast on Saturday morning, May 5, 1951, in the Bamboo Room of the Hotel Rogers in Bloomington. At this meeting the Council accepted the invitation of East-

ern Illinois State College to meet on its campus for the 45th annual meeting in May 1952. Hiram F. Thut was elected Second Vice-President to be in charge of local arrangements.

Two new members were appointed to the Publications Committee with terms to expire in 1954. They were Leo R. Tehon and Paul R. Shaffer.

Miss Jane V. Olson was appointed Technical Editor of the *Transactions*.

A standing committee was appointed by President Neckers to be known as the Junior Academy Advisory and Scholarship Committee. The members follow:

Leo R. Tehon, *Chairman*
L. J. Thomas
W. B. Welch
F. H. Reed
R. L. Smith

This committee was charged with coordinating the activities of the Senior and Junior Academies.

The second meeting of the Council was held on October 13, 1951, in room 208 of the Chemistry Building at the University of Chicago, with Dr. Neckers presiding. May 2 and 3, 1952, were chosen as the dates for the 45th annual meeting. Preliminary plans for the annual meeting were presented by Dr. Thut. George E. Ekblaw was appointed by the President to investigate the possibility of permanent sponsorship of the evening annual public lecture by the Society of the Sigma Xi.

A series of reports by Section Chairmen were presented. G. Q. Lefler reported for physics, H. W. Crall for psychology and education, K. E. Damann for botany, and T. N. Tahmisian for zoology. The Secretary was instructed to prepare the program for the 45th annual meeting with times designated for the papers to be given in each section and a definite and similar time for the business meeting in each section. F. O. Green reported for the Sustaining Membership Committee. He and his committee had already begun work and some payments had been received. Dr. Green suggested the possibility of additional income from sustaining members and was requested to submit recommendations after contacting the other committee members.

The third meeting of the Council was held on January 12, 1952, in the Conference Room of the Natural Resources Building in Urbana, Illinois, with Dr. Neckers presiding. Dr. Robertson reported on the meeting of the representatives of State Academies of Science held in conjunction with the annual meeting of the American Association for the Advancement of Science in Philadelphia, Pa., in December 1951. Dr. Robertson suggested that we might consider some papers at our annual meeting which emphasize the coordination of the sciences, that we attempt to interest Superintendents of Education to take cognizance of the educational value of the work science teachers give to science clubs, and suggested some methods for increasing funds from sustaining membership. Dr. Ekblaw reported progress in obtaining Sigma Xi sponsorship of the evening annual public lecture, and Dr. Neckers reported progress in obtaining speakers for the morning program of the annual meeting. Dr. Green sent a report for the Sustaining Membership Committee and Dr. Tehon reported for the Junior Academy Advisory and Scholarship Committee. Dr. Sanderson reported for the Research Grants Committee and Dr. Reed for the Science Talent Search Committee. Dr. Reed suggested the setting up of three subcommittees to handle matters of Scholarships, Awards, and Records of Achievement. The Council approved the setting up of the subcommittees.

Robert L. Smith reported for the Junior Academy. He told of plans for the 45th annual meeting including suggested improvements in past methods. This year a paper describing the exhibit will accompany each exhibit. A recess has been scheduled to allow members of the Senior Academy to visit the Junior Academy exhibits and to talk with the exhibitors. Mr. Smith mentioned possible cooperation between the Junior Academy and the National Science Fair. Dr. Thut submitted a complete outline of events for the 45th annual meeting and received high praise from the Council for his prompt and thorough work in planning for the meeting. The possibility of cooperation between the Academy and the National Science Fair was discussed at some length. It was the general feeling that the Council needed additional information before reaching a decision on the matter.

The fourth meeting of the Council was held Thursday evening, May 1, 1952, at the Hotel U. S. Grant in Mattoon with Dr. Neckers presiding. Dr. Thut reported that local arrangements for both Junior and Senior Academies were in readiness. Dr. Grim submitted the Treasurers Report which is to be presented to the entire membership on Friday, May 2.

REPORT OF THE TREASURER

For the Year May 1, 1951 to April 30, 1952

Balance on hand April 30, 1951		$1,599.69
Receipts		
Dues: annual members	$2,154.00	
Dues: life member	50.00	
Interest on Meyer real estate	12.00	
Interest from U. S. Savings Bonds, Series G	50.00	
Libraries	12.00	
Sales of Transactions	19.00	
Sales of reprints	307.99	
Research grant by the A.A.A.S.	220.00	
Registration fees—Illinois Wesleyan	189.00	
Junior Academy sustaining memberships	330.00	
		3,013.99
Total Receipts		$4,613.68
Expenditures		
Membership Chairman's expenses	120.85	
Council dinner & breakfast—Bloomington	71.47	
Council expenses during year	55.88	
Treasurer's office expenses	68.70	
Secretary's office expenses	207.12	
Librarian's expenses	154.17	
Section Chairmen's expenses	3.32	
Science Talent Winners' expenses	180.00	
Conservation Council	3.00	
Secretary, honorarium—2 years	300.00	
Editor, honorarium—$50.00 special	250.00	
Research grants	270.00	
Junior Academy expenses	611.93	
Editor's expenses	6.79	
Total Expenditures		2,303.23
Balance in Commercial National Bank of Peoria		$2,310.45
Statement of Resources, April 30, 1952		
Balance in Commercial National Bank of Peoria		$2,310.45
Certificate of interest for Meyer block leasehold		Value Unknown
United States Savings Bonds, Series G		2,000.00
Total Resources		$4,310.45

(Signed) W. W. GRIMM, *Treasurer*

REPORT OF THE COMMITTEE ON AUDITING

To the Illinois State Academy of Science:

Your committee on auditing respectfully submits the following report:

We have examined the records of the Treasurer, W. W. Grimm, for the year May 1, 1951 to April 30, 1952, and find them correct. The present financial status of the Academy is as follows:

Cash on deposit with the Commercial National Bank of Peoria	$2310.45
Series G, U. S. Savings Bonds, twenty (20)	2000.00
Meyer Block Leasehold Certificate No. 15	(Value Unknown)
Assets	$4310.45

(Signed) WILLIAM A. RYAN, JR., *Chairman*
WILLIAM AZBELL
DAN MORSE, M. D.

Mr. Smith reported on the expanded circulation of the Junior Academy Newsletter and that sectional meetings for the Junior Academy are planned for this year's annual meeting. Mr. Smith reported that the Junior Academy has been very active this year and was commended by the Council for his leadership. Dr. Robertson reported that the Museum Committee is active and working toward new housing for the Museum. Various section chairmen reported that everything was in readiness for the meetings on Friday, May 2. Dr. Shoemaker reported for the Conservation Committee and Dr. Tehon for the Junior Academy Advisory and Scholarship Committee. A report of special interest was given by G. H. Boewe as chairman of the Membership Committee. In response to a very large mail campaign a minimum of 240 new members have been added to the Academy during the past year or an increase of approximately 25 percent. Mr. Boewe was accorded high praise for his efforts. O. B. Young reported for the Research Grants Committee and suggested setting up a deadline for the submission of requests for grants. Dr. Reed reported for the Science Talent Search Committee. This year certificates have been prepared for the winners and the committee is beginning to compile information on the achievements of past winners. Dr. Green, chairman, reported that the Sustaining Membership Committee had contacted 78 firms or persons for possible new membership or continuation of previous membership. He suggested closer contact between the Academy and its sustaining members.

A. G. Wright proposed some recommendations for the guidance of the Publications Committee to reduce printing costs and costs for reprints. The recommendations were transmitted to the Publications Committee. Mr. Wright was appointed by the Council to the position of Assistant to the Librarian. Dr. Ekblaw reported that sponsorship of the evening annual public lecture by the Sigma Xi has been considered by the Illinois Chapter and has been referred to other chapters for their consideration. O. B. Young reported that the Committee on History of the Illinois Academy has served its purpose and should be discharged. The Council approved the dissolution of this committee. J. H. Kraus, coordinator of the National Science Fair addressed the Council concerning possible cooperation between the Academy and the National Science Fair. Following questions and discussion consideration of the proposal was held over for action by the new Council.

ANNUAL BUSINESS MEETING

The annual business meeting of the Illinois State Academy of Science was held May 2, 1952, in the Auditorium of the Main Building of Eastern Illinois State College at 5:00 p.m. with President J. W. Neckers presiding.

The Secretary's Report, which follows, was accepted.

The Illinois State Academy of Science held its first Council Meeting for the 1951-52 year in the Bamboo Room of the Hotel Rogers in Bloomington, Illinois, on May 5, 1951. Subsequent meetings of the Council were held on October 13, 1951 in room 208 Chemistry Building at the University of Chicago; on January 12, 1952, in the Conference Room of the Natural Resources Building at Urbana; and on May 1, 1952, at the Hotel U. S. Grant in Mattoon.

The deliberations and activities of the Council have been compiled by the Secretary, are presented at this meeting, and will appear in the *Transactions*.

Since the activities of the Council will be published and distributed to the membership, the Secretary to conserve time suggested that the reading of the rather lengthy minutes of meetings be omitted.

The report of the Treasurer, W. W. Grimm, was accepted. A copy of this report follows, together with the report of the Auditing Committee and the Commercial National Bank of Peoria.

M. W. Sanderson reported for the Research Grants Committee. He called to the group's attention the availability of funds to support research activity.

H. R. Wanless reported for the Nominating Committee which consisted of Thorne Deuel, Chairman, H. J. Eigenbrodt, Robert F. Paton, and H. R. Wanless. He presented a slate of officers for the 1952-53 year and a roster of committee chairman and committee personnel. This list will be published in the program for the 46th annual meeting and later in the Transactions. Dr. Wanless moved the acceptance of the report. The motion was seconded and passed. No nominations were made from the floor. E. L. Stover moved that the Secretary be instructed to cast a ballot for the election of those nominated. The motion was seconded and passed.

O. B. Young reported for the Resolutions Committee. Ten resolutions were submitted and recommended for approval by Dr. Young. Nine of the resolutions were seconded for approval and one was referred to the Council for further study. A copy of the resolutions adopted follows.

SHORTAGE OF SCIENTISTS

Whereas: the present trend in secondary education is toward the deemphasis of science subjects, and

Whereas: many of our future potential scientists are not given a good opportunity to develop a serious interest in a scientific career, and

Whereas: in view of the established current and future shortage of scientists,

Be it resolved, by the Illinois State Academy of Science, assembled in its 45th annual meeting, that the Illinois Legislative Commission on Education be urged to include in its considerations and recommendations provisions that will effect programs in education to alleviate this shortage, and

Be it further resolved, that the Secretary be and is hereby directed to send a copy of this resolution to the Chairman of the Legislative Commission and that the Council of the Academy take any steps necessary to support this resolution.

PUBLICATION OF TRANSACTIONS

Whereas: two years ago the State of Illinois, acting through its Museum, withdrew for technical reasons its financial support of the publication of the *Transactions* of the Illinois Academy of Science, and

Whereas: due to new legislation passed last year, the State of Illinois renewed and resumed its long-time financial support of the publication of the *Transactions* of this Academy by providing special funds to the Museum, and

Whereas: this legislation resulted largely from the persistent and sacrifical efforts of the 1951 President of the Academy, Dr. Percival Robertson, therefore

Be it resolved, that the Illinois State Academy of Science express its appreciation to Dr. Robertson and to any other persons who assisted him for their highly meritorious and effective efforts in working toward the passage of revised legislation by the State of Illinois, permitting the resumption of publication of the *Transactions*.

INTRODUCTION OF EXOTICS

Whereas: The introduction of exotic species of vertebrates into the United States in the past has been a mixed blessing, and, among wild species, the desirability in many cases has been questionable, and

Whereas: Introductions of exotics into other areas (e.g. New Zealand, many species; Australia, several species; West Indian Islands, the mongoose; Europe and Great Britain, American squirrels and the muskrat) have caused innumerable difficulties, and

Whereas: Such introductions are seldom made without a compensatory loss among native species, therefore,

Be it resolved, that the Illinois Academy of Science go on record as opposing the introduction of exotics into the United States unless it is established beyond any reasonable doubt that (1) the introduction of such species will not affect the well-being of native species, and (2) that they will appreciably add to the economy and/or well-being of at least a large segment of the human population of the nation.

CONCERNING THE IMPORTANCE OF MEASURING ULTRAVIOLET SOLAR RADIATION AT METEOROLOGICAL STATIONS

Whereas: Recent researches have shown that the intensity of ultraviolet light at the earth's surface is largely controlled by the density of a layer of ozone in the upper atmosphere which suggests that the intensity of solar ultraviolet radiation at the earth's surface is more of a meteorological than an astronomical problem; and

Whereas: It has been experimentally demonstrated in the case of a ferret, an orthopterous insect, and poultry that long application of low intensities of ultraviolet light is a reproductive stimulus, and

Whereas: Correlations between ultraviolet intensity and populations of chinch bugs and quail have been demonstrated, and

Whereas: Ultraviolet radiation records help to explain variations in insect pest and wildlife populations, and

Whereas: There is widespread interest in measuring solar radiation, its absorption and dissipation, and the effect it produces in all its ramifications, and

Whereas: There is a known relation between the incidence of skin cancer in different parts of the country and the

relative intensity of solar irradiation, therefore,

Be it resolved, that the Illinois State Academy of Science support the Ecological Society of America in emphasizing the importance of measurement of solar radiation and its components, especially that of ultraviolet radiation, at the major meteorological stations in North America, and in respectfully requesting the U. S. Department of Commerce Weather Bureau to give serious consideration to a policy of gradual expansion of its recording program, first to records of ultra-violet radiation and eventually to more complete analysis of solar radiation.

STREAM POLLUTION

Whereas: while certain industries and municipalities have made notable improvements in their methods of waste disposal, they are in a minority, and

Whereas: the pollution of streams by industries and municipalities remains a deplorable situation and a cause for alarm,

Be it resolved, that the Illinois State Academy of Science urge the proper officials of the State of Illinois to take measures to correct the present situation and to prevent additional pollution of the waters of the state.

JUNIOR ACADEMY OF SCIENCE

Whereas: a quarter of a century ago, in 1927, the Junior Academy of Science was founded by Lyell J. Thomas, and

Whereas: since that time he has given it his continuous and conscientious support and encouragement, and

Whereas: the Junior Academy has developed to such an extent that scientific interest has been aroused in many young people of this State of Illinois, and is now a major activity of the Academy,

Be it resolved, that the Illinois State Academy of Science express to Dr. Thomas its appreciation for the highly valuable and effective part he has played in the organization and development of the Junior Academy.

SCIENCE TALENT SEARCH

Whereas: the Science Talent Search program has become a major feature of the Junior Academy of the Illinois State Academy of Science, and

Whereas: largely through the very meritorious efforts of Frank H. Reed, Chairman of the Science Talent Committee, this program has become outstanding among the science academies of the nation,

Be it resolved, that the Illinois Academy of Science take this means of recognizing the important work of Dr. Reed and of expressing its appreciation to him and all others who have in any way contributed to the success of the Science Talent Search program.

TREASURER

Whereas: W. W. Grimm has been the Treasurer of the Illinois Academy of Science for the past five years, and

Whereas: while so serving this important function of the Academy, he has rendered notable effective and efficient service, and

Whereas: he will be unable hereafter to continue in office,

Be it resolved, that the Academy recognize publicly his faithful efforts and convey to him this appreciation of his fine record as Treasurer.

APPRECIATION TO HOST

Whereas: the excellent arrangements and provisions for this 45th annual meeting of the Illinois Academy of Science by its host, the Eastern Illinois State College, have contributed so greatly to the success of this meeting,

Be it resolved, that this Academy express its sincere thanks to Hiram F. Thut, Second Vice-President, who was in charge of local planning, and to all other persons who served in any capacity in accommodating the interests and activities of the members during this meeting.

(Signed) O. B. YOUNG, *Chairman*
WESLEY CALEF
ALICE L. KIBBLE
H. E. PHIPPS

IN MEMORIAM

An additional resolution was introduced by G. E. Ekblaw and adopted.

Be it resolved, that the Illinois State Academy of Science express to the families of Academy members who died during the past year its condolences.

A list of members who died during the past year follows:

Elsie P. Anderson
Edward Hugh Bangs
William O. Blanchard
Gilbert Ames Bliss
Hobart W. Cromwell
Robert Francis Fuelleman
Ernest Gates
Jens Jensen
John B. Ruyle
Wilbur Rudolph Tweedy

OJS exchange